NATIONALGEOGRAPHIC.COM/MAGAZINE | JULY 2009

NATIONAL GEOGRAPHIC

Angkor

WHY AN ANCIENT CIVILIZATION COLLAPSED

SPECIAL SUPPLEMENT: THE KHMER EMPIRE

NATIONAL GEOGRAPHIC

Southeast Asia

MONSOON LATITUDES

The Indochina Peninsula seems to pour from the eastern bend of the Himalaya. The peninsula's sinuous ranges, divided by epic rivers like the Mekong and Irrawaddy, owe their north-south orientation to India's tectonic collision with Eurasia, which began to raise the Himalaya and the Plateau of Tibet 50 million years ago. Some 180 million years earlier, the blocks of land that make up Southeast Asia had also crashed into the continent from the south. When these pieces first docked with Eurasia and each other, they created mountains that lay more parallel to the continent. India's arrival slowly wrenched the peninsula clockwise and rejuvenated the ranges. The rise of the Tibetan Plateau set up monsoon patterns that now drench Southeast Asia from May through October with virtually all its annual rain.

MYANMAR (BURMA) The Irrawaddy River Basin dominates otherwise mountainous Myanmar, renamed in 1989 by the governing military regime. Sweeping along the Bay of Bengal, the low-lying Arakan Yoma range reemerges to the south as India's Andaman and Nicobar Islands. This coastal range, as well as the undersea ridge on which the islands lie, is formed from sediments scraped off the oceanic part of the Indian plate as it dives under Eurasia.

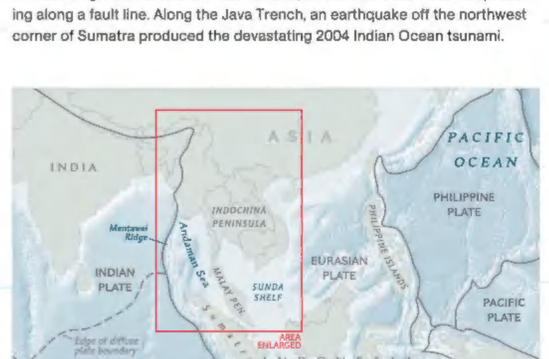
THAILAND From rain-fed tributaries in Thailand's northern mountains, the Chao Phraya River spreads sediments to create a fertile central plain. In the east, tectonic uplift pushed the Khorat Plateau as high as 3,000 feet on its southwest corner, though the average elevation of this thin-soiled upland is only 600 feet. Teak and other valuable hardwoods once covered half of Thailand, which outlawed logging in 1989 to preserve its remaining forest cover—now, on a rebound, at 30 percent.

LAOS Khone Falls—six miles of cataracts on the Mekong River in southern Laos—kept the longest river in Southeast Asia from becoming a trade route to China. With fewer than seven million people, the region's smallest population, Laos faces pressure to dam its stretch of the Mekong to export hydropower. The river is now dammed only in China. Northeast of Khone Falls, the fertile Bolovens Plateau is an isolated extrusion of basaltic lava. As a link on the Ho Chi Minh Trail, much of which ran through Laos, the plateau was heavily bombed during the Vietnam War.

VIETNAM "Nine Dragons," or Cuu Long, is the traditional name of the Mekong in Vietnam, where the river splits into multiple streams to end its 2,600-mile run from China in the maze of the Mekong Delta. North of the Annam Cordillera—the country's forested backbone that reaches to more than 8,500 feet—the Red River Delta fans out beyond Hanoi. Tracing an active fault line, the Red River follows a straight course for most of its journey.

CAMBODIA The liquid heart of Cambodia, Tonle Sap expands to four times its size during the rainy season. Flooding begins when the great lake's main outlet, the Tonle Sap River, reverses its course to flow north into the lake, carrying water from the swollen Mekong. The lake and its floodplain are vital to the country's rice farming and fishing. As a seasonal wetland for migrating birds and other wildlife, it is recognized as a UNESCO biosphere reserve.

MALAY PENINSULA This distinctive tail of land (left) is an illusion of modern sea levels. The Malay Peninsula and mainland Southeast Asia, as well as nearby islands of Indonesia, are one landmass. The submerged part of this land—its continental shelf—is the Sunda Shelf (below). When the Sunda Shelf was above sea level at the height of the last Ice Age 21,000 years ago, the rivers of the Indochina Peninsula extended far beyond their current deltas. Along the shelf's south and west, the oceanic edges of the Australian and the Indian plates dive under the Eurasian plate, creating the Java Trench and the Mentawei Ridge. This action gave birth to the Andaman Sea, where new ocean floor is spreading along a fault line. Along the Java Trench, an earthquake off the northwest corner of Sumatra produced the devastating 2004 Indian Ocean tsunami.



Land Cover Some areas are mixtures of land cover types.

Population · Swamp · Glacier · Forest · Grassland · Bare Ground

Map Legend

- Archaeological site
- International airport
- Gas field
- Oil field
- Passenger railroad
- Road

City Population

More than 5 million	BANGKOK, Phnom Penh
1 to 5 million	Ipoh, Hue
500,000 to 999,999	Louangphrabang
100,000 to 499,999	Loikaw
50,000 to 99,999	
Fewer than 50,000	

HOTINE OBLIQUE MERCATOR PROJECTION
SCALE 1:4,300,000
1 CENTIMETER = 43 KILOMETERS; 1 INCH = 68 MILES
0 75 150 KILOMETERS
0 75 150 STATUTE MILES

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NATIONAL GEOGRAPHIC

the Khmer Empire

CAMBODIA'S MEDIEVAL SPLENDOR

When the towers of the incomparable temple Angkor Wat rose in the mid-1100s, the Khmer Empire was still a half century away from its peak. Over the course of 600 years, Khmer kings ruled much of Southeast Asia from their imposing capital, Angkor, building temples that rank among the world's great works of art. Angkor's wealth came from rice and the engineering of a water system that ensured a good harvest. Even as the empire faded and forests reclaimed the capital, Angkor Wat never ceased to be a place of worship and remains the symbol of modern Cambodia.

The multiheaded, hooded water snake called a naga *is central to Khmer mythology, controlling the rains and bringing prosperity.*

A Hindu symbol common in Angkor temples, a trident may have crowned the central tower.

Angkor Wat

ART BY TOM CHANDLER AND MICHAEL LIM, MONASH UNIVERSITY

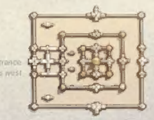
Living Landscape of Greater Angkor

Across the vastness of rice fields and along the embankments of temple moats and canals, residents of the imperial capital built timber houses on stilts, a precaution against flooding monsoon rains. Temple moats were a link in Angkor's system of canals and immense reservoirs, designed to control the seasonal deluge and capture water for later use. At its height in the 13th century, Greater Angkor was the most extensive urban complex in the world, about the area of New York City's five boroughs, with as many as 750,000 people.

Angkor Wat

The world's largest religious monument, erected in less than 40 years, was dedicated to the Hindu god Vishnu. It has been a Buddhist temple, or *wat*, since at least the 15th century. Though never overgrown with vegetation like most temples after the empire's decline, its towers and exquisitely carved galleries have suffered with age.

Temple entrance faces west



SACRED GEOMETRY

Angkor Wat mirrors the Hindu cosmos. The five towers of the central shrine are the peaks of mythical Mount Meru, seat of the universe and home of the gods. Concentric walls are mountain ranges beyond Meru.

In its prime the sandstone Temple would have gleamed with whitewash and perhaps colored tint. The towers, shaped like lotus buds, were gilded. Some experts think the towers may have flown pennants.

The Driving Spirits

Hinduism and Buddhism came to Southeast Asia through maritime trade with India before the first millennium A.D. Early Khmer kings built temples for Hindu deities and saw themselves as semidivine. At the empire's height, the focus shifted to Buddhism, the main faith in Cambodia today. Then, as now, the Khmer also honored nature spirits called *neak ta*.

Vishnu

Shiva

Brahma

Buddha

Hinduism

Of the three supreme Hindu gods (left), Vishnu and Shiva were most often chosen as patrons by Khmer kings. All three gods were represented in a symbol of Shiva, the lingam (right), an object of worship in every temple. Usually set in an open base (the female yoni), the lingam was anointed by priests with milk and other libations as the source of life.

LINGAM, 10TH CENTURY (1.8 FT TALL). MUSÉE GUIMET, PHOTO: RÉUNION DES MUSÉES NATIONAUX/ART RESOURCE, NY

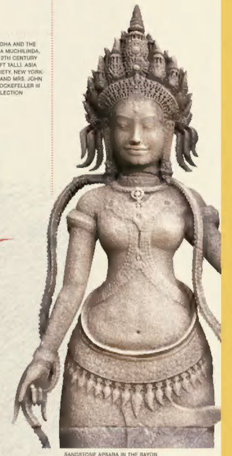
Buddhism

Though Buddhism became the empire's state religion in 1181, the Hindu gods remained. The Khmer synthesis of faiths was expressed in the cult popularity of the story depicted by this statue (right): A many-headed, Hindu water-snake deity, a naga, came ashore to elevate and shelter the Buddha, who, meditating beside a lake, was oblivious to a coming storm.

BUDDHA AND THE NAGA MUCHILINDA, CA 13TH CENTURY (2.4 FT TALL). ASIA SOCIETY, NEW YORK; MR. AND MRS. JOHN D. ROCKEFELLER III COLLECTION

CELESTIAL DANCERS

Beautiful spirits called apsaras (below) arose from the foam in a Hindu creation myth, Churning of the Sea of Milk. They dance and sing for the gods and mortals who reach paradise. Some 1,700 apsaras are carved on the walls of Angkor Wat alone; thousands more—individual in dress, hairstyle, and ornamentation—appear in almost every Angkor temple, Hindu and Buddhist alike. Classical Cambodian dance echoes an apsara's graceful gestures.



SANDSTONE APSARA IN THE BAYON TEMPLE (APPROX. 3 FT TALL). PHOTO: JUAN VELASCO

SUPPLEMENT TO NATIONAL GEOGRAPHIC MAGAZINE, JULY 2009

DESIGN: JUAN VELASCO
ART: BRUCE MORSER **TEXT:** JANE VESSELS
RESEARCH: ROBIN T. REID
PRODUCTION: MOLLY SNOWBERGER
CONSULTANTS: GREATER ANGKOR PROJECT, A COLLABORATION OF APSARA, FRENCH SCHOOL OF ASIAN STUDIES (EFEO), AND UNIVERSITY OF SYDNEY; MICHAEL D. COE, YALE UNIVERSITY; ROLAND FLETCHER, UNIVERSITY OF SYDNEY; HELEN ibbitson JESSUP, FRIENDS OF KHMER CULTURE; MARTIN POLKINGHORNE, UNIVERSITY OF SYDNEY; CHRISTOPHE POTTIER, EFEO
TIME LINE MAPS: GABRIELLE KIRKINGTON, MITCH HENDRICKSON, AND ANDREW WILSON, UNIVERSITY OF SYDNEY

MAJOR TEMPLES OF ANGKOR

Starting with Phnom Bakheng, set on a natural hill, he (phnom, by the king who founded Angkor as his capital, a major Khmer ruler typically erected one or more temples to establish his administrative center in the city. More than 50 large temples have been found, and across the nearly 400 square miles of Greater Angkor stood perhaps a thousand community shrines.

CARVED ROSETTE BORDER ON A COLUMN IN ANGKOR WAT. PHOTO: MICHAEL FREEMAN

An Empire's Rise and Fall

The temple ruins of the Khmer Empire were long known to Cambodians, but until 19th-century archaeologists translated the Sanskrit inscriptions on Angkor's temples, no one knew of the kings who built them. The empire rose in the ninth century from an array of fiefdoms. Why it dissolved in the 15th century is debated. Multiple forces were in play: war with other kingdoms, struggles among the Khmer elite, new social concepts from Theravada Buddhism, global trade shifts, and erratic monsoons that could have overwhelmed the ability of Angkor's masterful water system to provide a stable rice harvest.

A.D. 500

500–550 The earliest recorded Khmer ruler is Rudravarman. As with future Khmer kings, his throne name combines the name of a Hindu god or a powerful attribute with the suffix *varman*, meaning "protected by." Tradition holds that he ruled from Angkor Borei, a center of early Khmer cultural and political development, known for works such as this sandstone statue of Vishnu (below).

VISHNU, LATE 6TH–EARLY 7TH CENTURY (8.4 FT TALL). NATIONAL MUSEUM OF CAMBODIA, PHNOM PENH. PHOTO: JOHN GOLLINGS

600

611 Date of the earliest known Khmer inscription, on a stone block at Angkor Borei. The Khmer script, still used in Cambodia today, is an adaptation of Brahmi, the Indian script used to write Sanskrit. In the Khmer Empire, Sanskrit was the language for inscriptions concerning regal or ritual events; Old Khmer was the language used for practical matters. The Old Khmer inscription on a seventh-to-eighth-century stela (right) describes the delivery of salt to several temples devoted to Shiva. The mythical bull Nandin, Shiva's customary mount, rests on a lotus at top.

700

700s Political maneuvering and battles for territory characterize the Khmer fiefdoms, controlled by powerful families. Khmer society was highly stratified. Though strongly influenced by Indian culture, the Khmer never adopted the caste system.

STELA WITH KHMER SCRIPT, 7TH–8TH CENTURY (3 FT TALL). NATIONAL MUSEUM OF CAMBODIA. PHOTO: LUCA I. TETTONI, CORBIS

800

802–850 Reign of the founder of the Khmer Empire, Jayavarman II. Declared "universal monarch," he unifies rival fiefdoms and, on the plain near where Angkor will later rise, places his capital, Hariharalaya (map below). Its ruins are known as the Roluos Group.

877–889 Indravarman I builds the first of the empire's great reservoirs, called a *baray*.

889–900 Yashovarman I establishes Angkor as the capital; builds Phnom Bakheng temple and the East Baray.

900

Circa 928 Jayavarman IV rules from Koh Ker, where he has estates some 50 miles northeast of Angkor. There he builds a new urban center, with his palace, a baray, and a stepped pyramid temple to Shiva.

944 Rajendravarman II returns the capital to Angkor. The name "Angkor," from the Sanskrit word for "city," was given to the capital only in the 16th century. Temple inscriptions during imperial times call it Yashodharapura, "glory-bearing city."

1000

1011–1049 Reign of Suryavarman I, who wins the throne after nearly a decade of warfare between rival fiefdoms. He expands the empire's territory and starts constructing the West Baray. This reservoir, five miles long and a mile and a half wide, still functions today. Angkor's barays were sacred sites and integral to the city's complex water system, which ensured a reliable rice harvest.

1060s onward Periods of territorial revolts and rivalries.

1100

1113–ca 1150 Reign of Suryavarman II, builder of Angkor Wat. He wins new land for the empire and strengthens diplomatic relations with China.

1181–ca 1215 Reign of Jayavarman VII (below), considered the greatest Khmer king. He revitalizes the empire, which had been torn by internal fighting and battle losses to Champa, a kingdom in what is now Vietnam.

JAYAVARMAN VII (4.5 FT TALL). NATIONAL MUSEUM OF CAMBODIA. PHOTO: LUCA I. TETTONI, CORBIS

1200

ca 1200 The empire reaches its greatest extent under Jayavarman VII (map). He builds the 3.5-square-mile walled enclosure of Angkor Thom in the heart of the capital, with the Bayon temple in the center. He makes Mahayana Buddhism the state religion.

1270s Images of the Buddha in Angkor are defaced; the cause of this brief Hindu radicalism remains unknown.

1296 Chinese diplomat Zhou Daguan visits Angkor; his report is a rare eyewitness account of the empire.

1300

Early 1300s Tales of Angkor from Zhou Daguan about his year in the capital (1296–97) give no impression of decline. Royal processions with elephants and gold-draped horses, festivals, fireworks, and Khmer hospitality made him reluctant to leave. But in the first decades of the 1300s, the empire loses vitality.

Theravada Buddhism becomes the official religion. More egalitarian than the Mahayana Buddhism of Jayavarman VII, it may have undermined deference to the Khmer elite.

1327 The last Sanskrit inscription carved in Angkor commemorates the ascension of a minor king. Archaeologists consider this the end of the Classic Khmer period.

1362–1392 Possible era of drought, according to modern tree-ring data.

1400

Early 1400s Armies from neighboring kingdoms—Champa to the east and Ayutthaya (today's Thailand) to the west—continue to win Khmer land, leaving a much reduced state (map below).

1415–1440 Possible era of drought.

1431 Ayutthaya, by its own accounts, takes control of Angkor and installs a ruler. Khmer elite set up new courts in Srei Santhor and other towns to the south (map, far right).

1500

1528 The official court of the Khmer elite moves to Lovek, on the Tonle Sap River, a tributary of the Mekong, which flows to the South China Sea. Lovek, like Phnom Penh, was an inland port of international maritime commerce, with large populations of Malay, Chinese, and Japanese traders.

Mid-1500s Renovations to temples in Angkor, which remain active Theravada Buddhist communities.

BUDDHIST WORSHIPPER, ANGKOR WAT, 15TH–16TH CENTURY (3 FT TALL). NATIONAL MUSEUM OF CAMBODIA. PHOTO: JOHN GOLLINGS

1600-1700

Early 1600s The wealth of the Khmer elite has shifted from rice-based tax revenues to overseas maritime trading.

Early 1700s Vietnam annexes the Mekong River Delta, cutting off river access to the South China Sea. Cambodia's western coast offers no easy harbors.

REDISCOVERY

1860 French naturalist Alexandre-Henri Mouhot visits the ruins of Angkor, following up on the account of a French missionary. Publication of his drawings and journals begins the rediscovery of Angkor by the Western world.

ANGKOR THOM GATE, BY LOUIS DELAPORTE, 1873. PHOTO: LEONARD DE SELVA, CORBIS

PHOTO: JUAN VELASCO

GUARDIANS AT THE BAYON

Monumental images have gazed serenely for 800 years from the towers of the Bayon, built by Buddhist king Jayavarman VII. The nearly 200 faces may have been carved to resemble the king but likely represent Lokeshvara, one of the bodhisattvas—beings that selflessly postpone their rebirth into enlightenment in order to stay on Earth to help others.

Chronicles in Stone

Sweeping bas-relief murals in the Bayon temple immortalize not only victorious battles but also daily Khmer life: childbirth, gambling, the marketplace. Because some murals are incomplete, we know how artisans sketched and incised a scene before carving. Some 1,300 inscriptions survive on Angkor's temples, but troves of records penned on palm leaves or bark disintegrated long ago.

THE CARVING PROCESS

PHOTO: JUAN VELASCO

FEAST PREPARATIONS

In a detail from the Bayon murals, a wild pig is dipped in boiling water to remove its bristles while rice cooks on a smaller fire. Loaves carried aloft may be sugar made from palm sap. At right, a man grills stacked skewers of fish.

THE LAWS OF GRAVITY DON'T APPLY TO EUPHORIA.

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THOMAS P. PESCHAK

These manta rays flip for food. Rolling like barrels, they suck up plankton in a fertile patch of a bay in the Maldives. Story on page 56.

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NATIONAL GEOGRAPHIC

DEPARTMENTS

CULTURE

Spread of the Amish

Population is up. So is development in longtime heartlands. Colorado, here they come!

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Send Us Your Corn Dogs

Actually, we don't want real ones. But we do want your photos of the greasy, battered treat and other state fair attractions for a special section of My Shot at *ngm.com/statefair.*

On the Cover

Forest roots at Ta Prohm temple are kept to evoke its pre-conservation look.
Photo by Robert Clark

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EDITOR'S NOTE

Thrill seekers take a whirl on a ride at the Texas state fair.

I got busted at the milk shake stand at my first state fair. My father had dropped me off along with my prize hog at the Salem fairgrounds for the Oregon State Fair's livestock competition. He paid for a week's food and lodging in the 4-H dorm and went to visit his parents for the day. When he returned, we went to the Dairy Bar. It came time to pay for my milk shake. I was broke. My father asked what I'd done with all the money he gave me. I confessed I'd spent it all in two hours on the bumper cars.

Garrison Keillor would have understood. "The state fair," he writes in this month's feature, "is a ritual carnival marking the end of summer…and the start of school and higher algebra and the imposition of strict rules." Strict rules are for later. The state fair is about now—and the chance for a 12-year-old to cut loose before a new school year. With corn dog in hand (to eat food with two hands is one of the ten top joys of a state fair, Keillor observes), I was strolling down the boardwalk when the bumper cars called. I got behind the wheel. Time and quarters raced away.

Extreme centrifugal force is number two on Keillor's list of state fair joys. He mentions the double Ferris wheel and flume ride. Sissy stuff. I'll take the bumper cars every time.

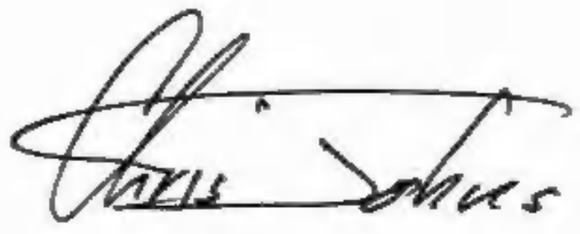

PHOTO: JOEL SARTORE WITH CHARLES RASH

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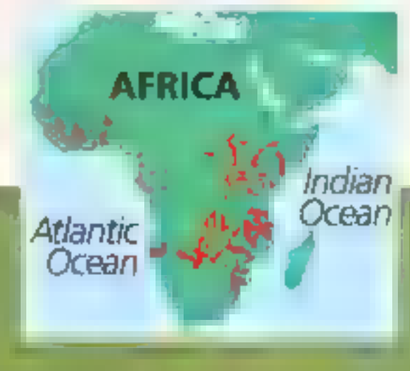

Hippopotamus *(Hippopotamus amphibius)*
Size: Body length, 300 - 540 cm (118.1 - 212.6 inches); shoulder height, 130 - 165 cm (51.2 - 65 inches); tail, approx. 56 cm (22 inches) **Weight:** 655 - 3,200 kg (1,444 - 7,055 lbs) **Habitat:** Found in most major rivers in sub-Saharan Africa; requires a permanent supply of water near large grazing areas **Surviving number:** Estimated at 125,000 - 148,000

Photographed by Beverly Joubert

WILDLIFE AS CANON SEES IT

Fearsome, yes. But fragile, too. The hippopotamus is built like a tank, runs far faster than a man, and defends its territory with massive, razor-sharp tusks. Yet the enormous herbivore has a sensitive side; it spends all day in the water to prevent its thin skin from drying out, and secretes an oily reddish-pink substance to protect it from sunburn. It is also the linchpin in a finely balanced wetland ecosystem: if the hippopotamus and its fertilizing dung are removed, local fish populations crash. Facing both habitat loss and poaching for meat and tusks, the hippopotamus is disappearing from its former range on a frighteningly large scale.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit **canon.com/environment** to learn more.

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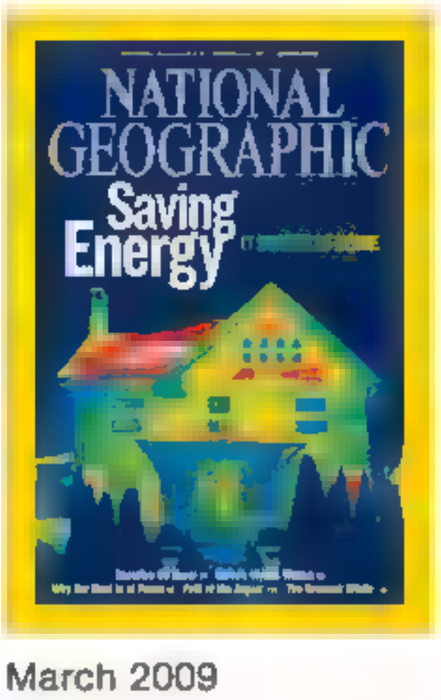
LETTERS



March 2009

law and the process is already well under way. Companies must submit detailed reclamation plans to government regulators prior to starting their projects and must pay a deposit into a government-administered fund over the project's life. To date, more than 25 square miles have been reclaimed.

DAVID COLLYER
President, Canadian Association of Petroleum Producers
Calgary, Alberta

Scraping Bottom: The Canadian Oil Boom

I am a Canadian citizen and can assure you that not all Canadians favor the "development" of the oil sands. I believe that this is ■ shortsighted jump into disaster. I believe that the appropriate full environmental assessment has not been completed and that all the people affected have not been consulted and heard.

PETER MOGK
Milverton, Ontario

Oil sands mines are expensive, large-scale, long-life projects with a significant impact on the landscape before they are fully reclaimed. Industry has never argued this point. However, environmental impacts must be considered in context. Oil sands development creates hundreds of thousands of jobs and billions in investment and government revenues. The Canadian oil sands have a significant role to play in providing North America ■ means to reduce dependence on petroleum energy supply from less secure regions. The article provided no images of reclaimed sites, even though full reclamation is required by

According to the government of Alberta, to date, 0.4 square miles of oil sands mining areas have been certified reclaimed. Another 25 square miles are now in the process of reclamation.

Some environmental groups have called for a halt to all oil sands mining. However, such a large reserve of hydrocarbons cannot be ignored and will certainly be developed. A regulated approach, with projects spaced at reasonable time intervals, would be wiser than the current policy. If parts of the deposit are not developed immediately, the reserve will only increase in value. A more measured approach will enable improved environmental procedures to catch up with production technology.

DOUG CRUICKSHANK
Calgary, Alberta

The greatest risk posed by Alberta's oil sands is the lobbying of politicians by oil sands companies to downgrade environmental standards and transfer responsibility for reclamation and waste to the taxpayers of Alberta.

TONY KAVANAGH
Calgary, Alberta

I worked in the oil sands and have done so for the past eight years. I do have concerns with the way the environment is raped and pillaged up here. I also have concerns as to how I will feed my family. The need for solid answers to these issues is of greater concern than the need to lash out at companies that feed the working half of Canada.

BILL RAHN
Armstrong, British Columbia

Saving Energy: It Starts at Home

Your article compared reducing personal CO_2 output with a new diet yet failed to mention that reducing meat in one's diet radically reduces CO_2 emissions. If you are serious about cutting down, simply start in your kitchen.

ROBERT JAMGOCHIAN
Mendocino, California

The idea that incremental energy savings by individuals could derail global warming is absurd. We need to solve the problem, not mitigate it. Make energy production CO_2 clean. No other action will suffice.

SETH SCOTT
Elmhurst, New York

Corrections, Clarifications

March 2009: Saving Energy
Pages 80-81: The central chart incorrectly labeled emissions in metric tons of CO_2. It should have been labeled CO_2e, or carbon dioxide equivalent, which allows consistency in aggregation by expressing other gases in terms of the benchmark CO_2.

Email ngsforum@ngm.com
Write National Geographic Magazine, PO Box 98199, Washington, DC 20090-8199. Include name, address, and daytime telephone. Letters may be edited for clarity and length.

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Odd Angles What do interspecies curiosity and age-old landmarks have in common? They're both parts of our world that can still seem new and surprising—it's all ■ matter of perspective. So find a point of view and upload the result to our website; your picture might be published in *National Geographic*. Every month, this page features two photographs: one chosen by our editors, and one chosen by readers via our online voting machine. For more information go to *ngm.com/yourshot*.

EDITORS' CHOICE

Conor Dupre-Neary Kula, Hawaii

When an "extraordinary" moth alighted at Dupre-Neary's living room window, the 27-year-old biological technician went outside for a better look. He got an even better picture: his dog, Jada, and the bug eyeing each other through the glass.

Susan Byrd Scottsdale, Arizona

Searching for "the essence of old China," Byrd, 65, found two farmers admiring the centuries-old rice terraces that ridge the steep hills of Longsheng. Her shot was voted an *ngm.com* favorite.

READERS' CHOICE

COPD? BREATHE BETTER.

ADVAIR HELPS SIGNIFICANTLY IMPROVE LUNG FUNCTION*

ADVAIR is different from most other COPD medications because it contains both an anti-inflammatory† and a long-acting bronchodilator working together to help you breathe better. Talk to your doctor and find out if ADVAIR is right for you.

Important information: ADVAIR DISKUS 250/50 is approved for adults with COPD, including chronic bronchitis, emphysema, or both. You should only take 1 inhalation of ADVAIR twice a day. Higher doses will not provide additional benefits. People with COPD taking ADVAIR may have a higher chance of pneumonia. Call your doctor if you notice any of the following symptoms: change in amount or color of sputum, fever, chills, increased cough, or increased breathing problems. ADVAIR may increase your risk of osteoporosis and some eye problems (cataracts or glaucoma). You should have regular eye exams. Thrush in the mouth and throat may occur. Tell your doctor if you have a heart condition or high blood pressure before taking ADVAIR. Do not use ADVAIR with long-acting $beta_2$-agonists for any reason. ADVAIR does not replace fast-acting inhalers for sudden symptoms.

Please see accompanying important information about ADVAIR DISKUS

*Measured by a breathing test in people taking ADVAIR 250/50, compared with people taking either fluticasone propionate 250 mcg or salmeterol 50 mcg. Your results may vary.

†It is not known how anti-inflammatories work in COPD.

‡Restrictions apply. See AdvairCOPD.com for eligibility rules.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

If you smoke and want to quit, you can learn more at way2quit.com.

Get your first full prescription FREE‡! Go to AdvairCOPD.com or call 1-800-511-4791.

Partnership for Prescription Assistance

If you don't have prescription coverage and can't afford your medicines, visit pparx.org, or call 1-888-4PPA-NOW (1-888-477-2669)

GlaxoSmithKline

ADVAIR DISKUS 250/50
(fluticasone propionate 250 mcg and salmeterol 50 mcg inhalation powder)

ADVAIR DISKUS® 100/50, 250/50, 500/50

(fluticasone propionate 100, 250, 500 mcg and salmeterol 50 mcg inhalation powder)

Important Information

This brief summary does not take the place of talking to your healthcare provider about your medical condition or treatment.

What is the most important information I should know about ADVAIR DISKUS?

- **In patients with asthma, long-acting $beta_2$-agonist (LABA) medicines, such as salmeterol (one of the medicines in ADVAIR DISKUS), may increase the chance of death from asthma problems.** In a large asthma study, more patients who used salmeterol died from asthma problems compared with patients who did not use salmeterol. It is not known whether fluticasone propionate, the other medicine in ADVAIR DISKUS, changes your chance of death from asthma problems seen with salmeterol. Talk with your healthcare provider about this risk and the benefits of treating your asthma with ADVAIR DISKUS.
- **ADVAIR DISKUS does not relieve sudden symptoms. Always have a fast-acting inhaler (short-acting $beta_2$-agonist medicine) with you to treat sudden symptoms. If you do not have a fast-acting inhaler, contact your healthcare provider to have one prescribed for you.**
- **Do not stop using ADVAIR DISKUS unless told to do so by your healthcare provider because your symptoms might get worse.**
- **ADVAIR DISKUS should be used only if your healthcare provider decides that another asthma-controller medicine alone does not control your asthma or that you need 2 asthma-controller medicines.**
- **Call your healthcare provider if breathing problems worsen over time while using ADVAIR DISKUS. You may need different treatment.**
- **Get emergency medical care if:**
  - **breathing problems worsen quickly, and**
  - **you use your fast-acting inhaler, but it does not relieve your breathing problems.**

What is ADVAIR DISKUS?

- **ADVAIR DISKUS contains 2 medicines:**
  - **fluticasone propionate (the same medicine found in FLOVENT®),** an inhaled corticosteroid medicine. Inhaled corticosteroids help to decrease inflammation in the lungs. Inflammation in the lungs can lead to asthma symptoms.
  - **salmeterol (the same medicine found in SEREVENT®),** a LABA. LABA medicines are used in patients with asthma or chronic obstructive pulmonary disease (COPD). LABA medicines help the muscles around the airways in your lungs stay relaxed to prevent symptoms, such as wheezing and shortness of breath. These symptoms can happen when the muscles around the airways tighten. This makes it hard to breathe. In severe cases, wheezing can stop your breathing and cause death if not treated right away.

Asthma

ADVAIR DISKUS is used long term, twice a day, to control symptoms of asthma and to prevent symptoms such as wheezing in adults and children ages 4 and older.

Chronic Obstructive Pulmonary Disease (COPD)

COPD is a chronic lung disease that includes chronic bronchitis, emphysema, or both. ADVAIR DISKUS 250/50 is used long term, twice a day, to help improve lung function for better breathing in adults with COPD. ADVAIR DISKUS 250/50 has been shown to decrease the number of flare-ups and worsening of COPD symptoms (exacerbations).

Who should not use ADVAIR DISKUS?

Do not use ADVAIR DISKUS:

- to treat sudden, severe symptoms of asthma or COPD
- if you have a severe allergy to milk proteins. Ask your doctor if you are not sure.

What should I tell my healthcare provider before using ADVAIR DISKUS?

Tell your healthcare provider about all of your health conditions, including if you:

- **have heart problems**
- **have high blood pressure**
- **have seizures**
- **have thyroid problems**
- **have diabetes**
- **have liver problems**
- **have osteoporosis**
- **have an immune system problem**
- **are pregnant or planning to become pregnant.** It is not known if ADVAIR DISKUS may harm your unborn baby
- **are breastfeeding.** It is not known if ADVAIR DISKUS passes into your milk and if it can harm your baby
- **are allergic to any of the ingredients in ADVAIR DISKUS, any other medicines, or food products**
- **are exposed to chickenpox or measles**

Tell your healthcare provider about all the medicines you take, including prescription and nonprescription medicines, vitamins, and herbal supplements. ADVAIR DISKUS and certain other medicines may interact with each other. This may cause serious side effects. Especially, tell your healthcare provider if you take ritonavir. The anti-HIV medicines Norvir® (ritonavir capsules) Soft Gelatin, Norvir® (ritonavir oral solution), and Kaletra® (lopinavir/ritonavir) Tablets contain ritonavir.

Know the medicines you take. Keep a list and show it to your healthcare provider and pharmacist each time you get a new medicine.

How do I use ADVAIR DISKUS?

Do not use ADVAIR DISKUS unless your healthcare provider has taught you and you understand everything. Ask your healthcare provider or pharmacist if you have any questions.

- Children should use ADVAIR DISKUS with an adult's help, as instructed by the child's healthcare provider.
- Use ADVAIR DISKUS exactly as prescribed. **Do not use ADVAIR DISKUS more often than prescribed.** ADVAIR DISKUS comes in 3 strengths. Your healthcare provider will prescribe the one that is best for your condition.
- The usual dosage of ADVAIR DISKUS is 1 inhalation twice a day (morning and evening). The 2 doses should be about 12 hours apart. Rinse your mouth with water after using ADVAIR DISKUS.
- If you take more ADVAIR DISKUS than your doctor has prescribed, get medical help right away if you have any unusual symptoms, such as worsening shortness of breath, chest pain, increased heart rate, or shakiness.
- If you miss a dose of ADVAIR DISKUS, just skip that dose. Take your next dose at your usual time. Do not take 2 doses at one time.
- Do not use a spacer device with ADVAIR DISKUS.
- Do not breathe into ADVAIR DISKUS.
- **While you are using ADVAIR DISKUS twice a day, do not use other medicines that contain a LABA for any reason. Ask your healthcare provider or pharmacist if any of your other medicines are LABA medicines.**
- Do not change or stop any of your medicines used to control or treat your breathing problems. Your healthcare provider will adjust your medicines as needed.
- Make sure you always have a fast-acting inhaler with you. Use your fast-acting inhaler if you have breathing problems between doses of ADVAIR DISKUS.

Call your healthcare provider or get medical care right away if:

- your breathing problems worsen with ADVAIR DISKUS
- you need to use your fast-acting inhaler more often than usual
- your fast-acting inhaler does not work as well for you at relieving symptoms
- you need to use 4 or more inhalations of your fast-acting inhaler for 2 or more days in a row
- you use 1 whole canister of your fast-acting inhaler in 8 weeks' time
- your peak flow meter results decrease. Your healthcare provider will tell you the numbers that are right for you.
- you have asthma and your symptoms do not improve after using ADVAIR DISKUS regularly for 1 week

What are the possible side effects with ADVAIR DISKUS?

- See *"What is the most important information I should know about ADVAIR DISKUS?"*
- Patients with COPD have a higher chance of getting pneumonia. ADVAIR DISKUS may increase the chance of getting pneumonia. **Call your healthcare provider if you notice any of the following symptoms:**
  - increase in mucus (sputum) production
  - change in mucus color
  - increased breathing problems
  - fever
  - increased cough
  - chills
- **serious allergic reactions.** Call your healthcare provider or get emergency medical care if you get any of the following symptoms of a serious allergic reaction, including:
  - rash
  - swelling of the face, mouth, and tongue
  - hives
  - breathing problems
- **increased blood pressure**
- **chest pain**
- **a fast and irregular heartbeat**
- **headache**
- **tremor**
- **nervousness**
- **weakened immune system and a higher chance of infections**
- **lower bone mineral density.** This may be a problem for people who already have a higher chance of low bone density (osteoporosis).
- **eye problems including glaucoma and cataracts.** You should have regular eye exams while using ADVAIR DISKUS.
- **slowed growth in children.** A child's growth should be checked often.

Other common side effects include:

- hoarseness and voice changes
- throat irritation
- thrush in the mouth and throat
- respiratory tract infections

Tell your healthcare provider about any side effect that bothers you or that does not go away.

These are not all the side effects with ADVAIR DISKUS. Ask your healthcare provider or pharmacist for more information.

Call your doctor for medical advice about side effects. You may report side effects to the FDA at 1-800-FDA-1088.

Ask your healthcare provider or pharmacist for additional information about ADVAIR DISKUS. You can also contact the company that makes ADVAIR DISKUS (toll free) at 1-888-825-5249 or at www.advair.com.

ADVAIR DISKUS, DISKUS, FLOVENT, and SEREVENT are registered trademarks of GlaxoSmithKline. Norvir and Kaletra are registered trademarks of Abbott Laboratories.

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ADD:4PI August 2008

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VISIONS OF EARTH

Tonga Plumes of ash, smoke, and steam billow thousands of feet into the air as an undersea volcano erupts on the uninhabited island of Hunga Ha'apai. The fallout, rock detritus known as scoria, has since enlarged the landmass.

PHOTO DANA STEPHENSON, GETTY IMAGES

Tanzania After two weeks of in-mouth incubation, a school of perhaps 200 cichlid fry—each less than half an inch long—swim free of their mother, searching for a plankton meal in the cerulean waters of Lake Tanganyika.

PHOTO ANGEL M FITOR

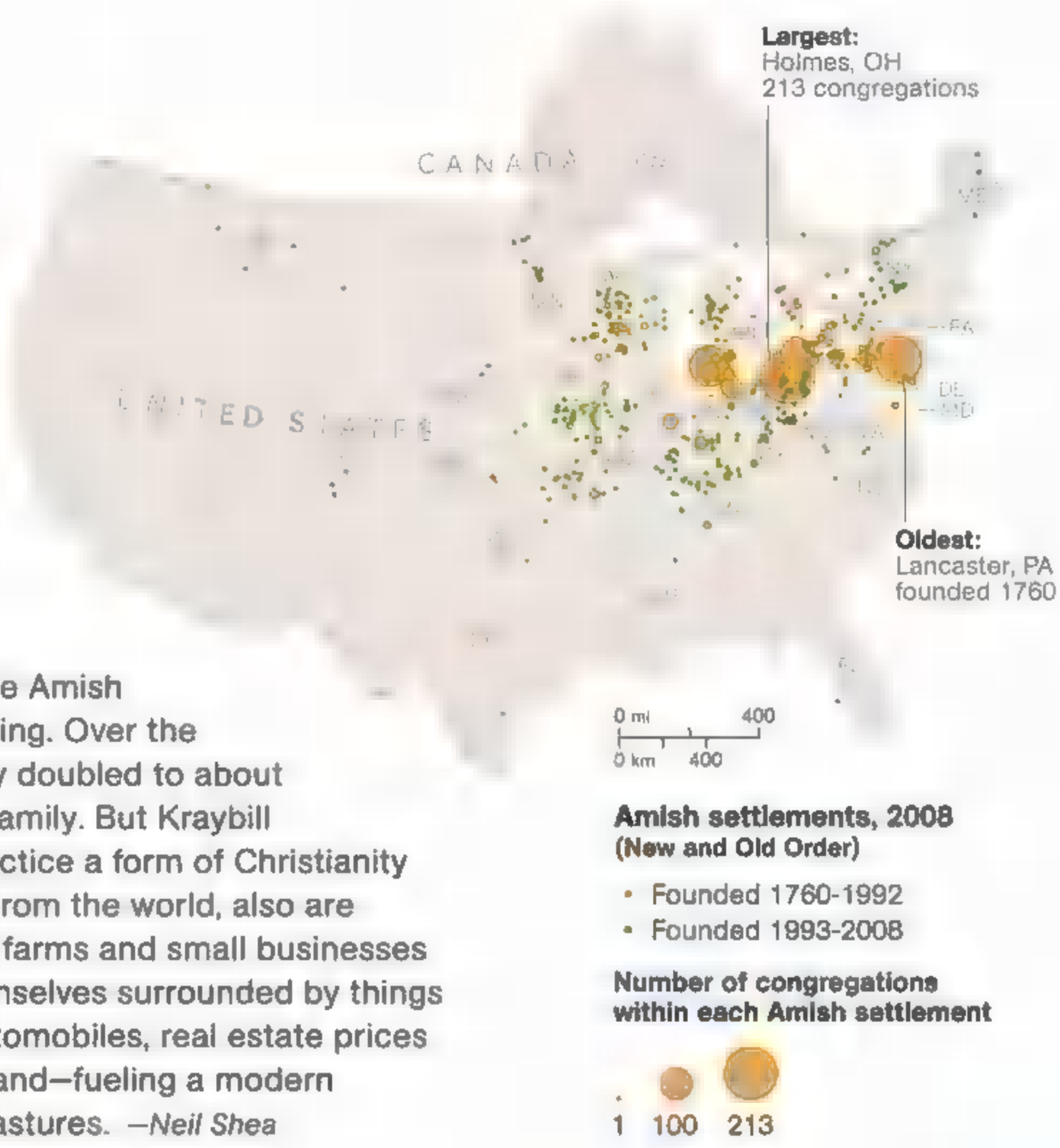
India In Jammu, a flower of flame blooms from a man's kerosene-filled mouth. Devotees of Sikhism, the world's fifth largest organized religion, were marking the 342nd birthday of Guru Gobind Singh, ■ founder of the faith.

PHOTO: JAIPAL SINGH, EPA/CORBIS

Spread of the Amish

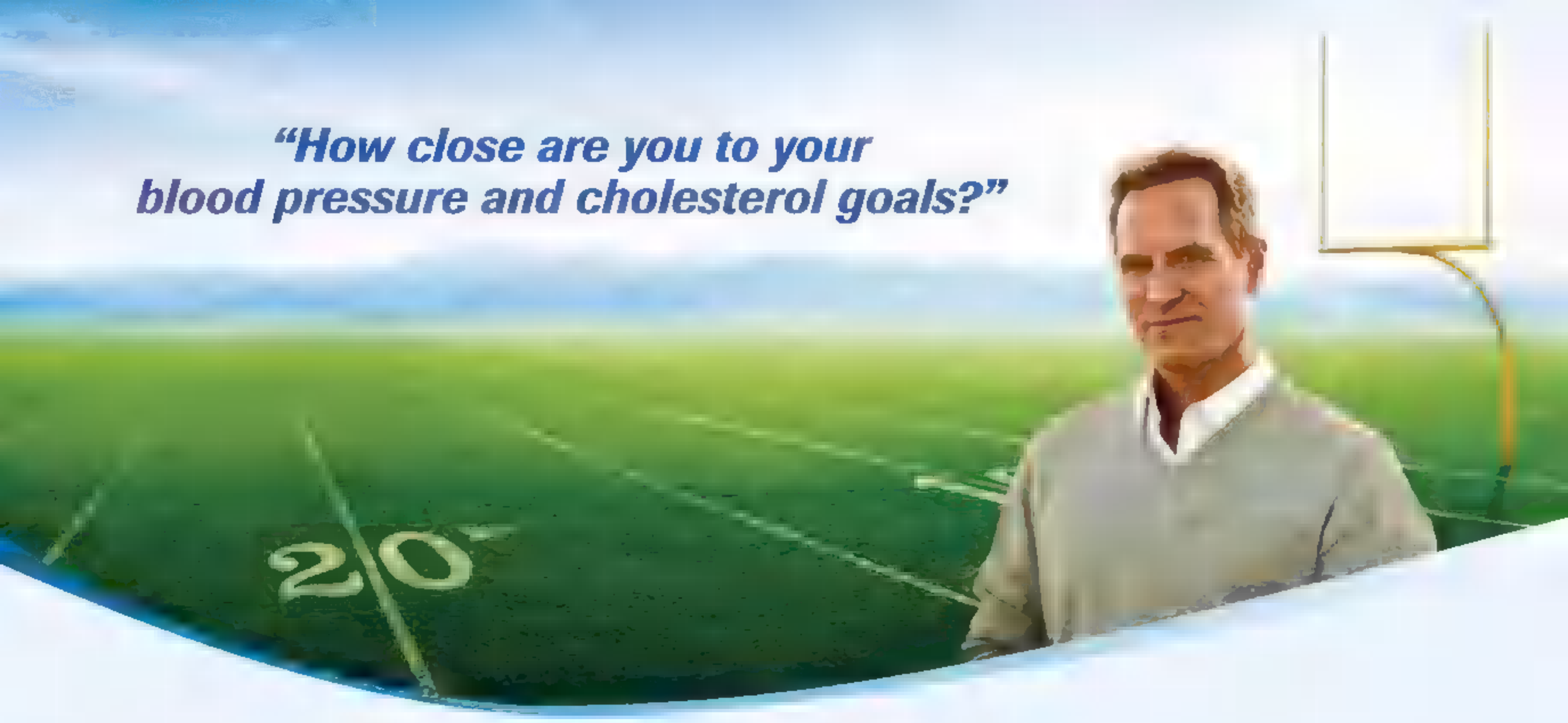
If you live in Colorado, say, or Maine, maybe you've noticed a new kind of traffic: Amish horse buggies. They're appearing in areas they've never been (or haven't been for a very long time), as Amish farming communities take root in states far beyond their traditional heartland of Pennsylvania, Indiana, and Ohio.

According to Donald Kraybill, a sociologist at Elizabethtown College, the Amish are moving partly because they're growing. Over the past 16 years, the population has nearly doubled to about 230,000, with roughly five children per family. But Kraybill explains that Amish adherents, who practice a form of Christianity emphasizing simplicity and separation from the world, also are feeling hemmed in. As towns near their farms and small businesses expand, Amish families have found themselves surrounded by things they've always tried to avoid—roads, automobiles, real estate prices that prohibit them from acquiring farmland—fueling a modern migration to greener, and more rural, pastures. *—Neil Shea*



Amish women walk a beach in Mississippi, one of several states in which new communities have arisen.

PHOTO: JOHNNY NICOLORO NGM MAPS SOURCE: YOUNG CENTER FOR ANABAPTIST AND PIETIST STUDIES



Ask your doctor if **Caduet** can help you go for both your goals.

Caduet®
amlodipine besylate/atorvastatin calcium
from 2.5mg/10mg to 10mg/80mg tablets

In a clinical study of patients with slightly elevated blood pressure and cholesterol, **Caduet helped 48% reach both goals in just 4 weeks.** Not all patients will reach their blood pressure and cholesterol goals. Individual results will vary.

Only Caduet combines the two proven medicines, Norvasc (amlodipine besylate) for high blood pressure and Lipitor (atorvastatin calcium) for high cholesterol, in a single pill to significantly lower both, when diet and exercise are not enough.

Ask your doctor if Caduet can help you go for both your goals and visit **www.caduet.com** to learn more.

IMPORTANT INFORMATION:

Caduet is a prescription drug that combines 2 medicines, Norvasc and Lipitor. Norvasc is used to treat high blood pressure (hypertension), chest pain (angina) or blocked arteries of the heart (coronary artery disease); Lipitor is used along with diet and exercise to lower high cholesterol. It is also used to lower the risk of heart attack and stroke in people with multiple risk factors for heart disease such as family history, high blood pressure, age, low HDL-C, or smoking.

Caduet is not for everyone. It is not for those with liver problems. And it is not for women who are nursing, are pregnant, or may become pregnant. If you take Caduet, tell your doctor if you feel any new muscle pain or weakness. This could be a sign of rare but serious muscle side effects. Tell your doctor about all of the medicines you take. This may help avoid serious drug interactions. Your doctor should do blood tests to check your liver function before and during treatment and may adjust your dose. If you have any heart problems, be sure to tell your doctor. The most common side effects are edema, headache, and dizziness. They tend to be mild and often go away.

Caduet can be used alone or with other high blood pressure medicines. Caduet is one of many options for treating high blood pressure and high cholesterol, in addition to diet and exercise, that you or your doctor can consider.

Please see the accompanying patient information on the following page.

You are encouraged to report negative side effects of prescription drugs to the FDA.
Visit www.FDA.gov/medwatch or call 1-800-FDA-1088.

IMPORTANT FACTS

Caduet® (CAD-oo-et)
amlodipine besylate/atorvastatin calcium

LOWERING YOUR HIGH BLOOD PRESSURE AND HIGH CHOLESTEROL

High blood pressure and high cholesterol are more than just numbers. They are risk factors that should not be ignored. If your doctor said you have high blood pressure and high cholesterol, you may be at an increased risk for heart attack or stroke. But the good news is, you can take steps to lower your blood pressure and cholesterol.

With the help of your doctor and a medicine like CADUET, along with diet and exercise, you could be on your way to lowering your blood pressure and cholesterol. Ready to start eating right and exercising more? Talk to your doctor and visit the American Heart Association at www.americanheart.org.

WHO IS CADUET FOR?

Who can take CADUET:

- Adults who need to lower their blood pressure AND who cannot lower their cholesterol enough with diet and exercise

Who should NOT take CADUET:

- Women who are pregnant, may be pregnant, or may become pregnant. CADUET may harm your unborn baby. If you become pregnant, stop CADUET and call your doctor right away.
- Women who are breast-feeding. CADUET can pass into your breast milk and may harm your baby.
- People with liver problems
- People allergic to anything in CADUET

BEFORE YOU START CADUET

Tell your doctor:

- About all the medicines you take, including prescription and nonprescription medicines, vitamins, and herbal supplements
- If you ever had heart disease
- If you have muscle aches or weakness
- If you drink more than 2 glasses of alcohol daily
- If you have diabetes or kidney problems
- If you have thyroid problems

ABOUT CADUET

CADUET is a prescription medicine that combines Norvasc® (amlodipine besylate) for high blood pressure and Lipitor® (atorvastatin calcium) for high cholesterol in one pill. CADUET, along with diet and exercise, treats both high blood pressure (hypertension) and high cholesterol. CADUET can lower the risk of heart attack or stroke in patients with risk factors for heart disease–such as heart disease in the family, high blood pressure, being older than 55, having low HDL-C, diabetes, or smoking.

POSSIBLE SIDE EFFECTS OF CADUET

Serious side effects in a small number of people:

Muscle problems that can lead to kidney problems. This includes kidney failure. You have a higher chance for muscle problems if you take certain other medicines with CADUET.

Liver problems. Your doctor may do blood tests to check your liver before you start CADUET and while you are taking it.

Symptoms of muscle or liver problems include:

- Unexplained muscle weakness or pain, especially if you have a fever or feel very tired
- Nausea, vomiting, or stomach pain
- Brown or dark-colored urine
- Feeling more tired than usual
- Your skin and the whites of your eyes turn yellow

If you have these symptoms, call your doctor right away.

Chest pain. Sometimes chest pain that does not go away or gets worse or a heart attack can happen. If this happens, call your doctor or go to the emergency room right away.

Common side effects of CADUET include:

- headache
- swelling of legs or ankles
- feeling dizzy
- constipation
- gas
- upset stomach and stomach pain

These side effects are usually mild and go away. There are other side effects of CADUET. Ask your doctor or pharmacist for a complete list.

HOW TO TAKE CADUET

Do:

- Take CADUET once a day as prescribed by your doctor.
- Try to eat heart-healthy foods while you take CADUET.
- Take CADUET at any time of day, with or without food.
- If you miss a dose, take it as soon as you remember. But if it has been more than 12 hours since your missed dose, wait. Take the next dose at your regular time.

Don't:

- Do not break CADUET tablets before taking them.
- Do not stop taking nitroglycerin, if you take it for angina.
- Do not change or stop your dose before talking with your doctor.
- Do not start new medicines or stop any medicines you are taking before talking to the doctor.

NEED MORE INFORMATION?

- Ask your doctor, health-care provider, or pharmacist. This is only a summary of the most important information.
- Go to **www.caduet.com** or call **(866) 514-0900.**

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Why would we do this? Our real goal is to build a long term client relationship with you. We are sure that most of you will become loyal Stauer clients in the years to come, but for now, in this lousy economy, we will give you these pearls to help with your future gift giving ideas.

We did find a magnificent cache of cultured pearls at the best price that I have ever seen. Our pearl dealer was stuck. A large luxury department store in financial trouble cancelled a large order at the last minute so we grabbed all of them. He sold us an enormous cache of his roundest, whitest, most iridescent cultured 5 ½–6mm pearls for only pennies on the dollar.

But let me get to the point: his loss is your gain. Many of you may be wondering about your next gift for someone special. In the past, Stauer has made gift giving easier with the absolute lowest prices on fine jewelry and luxury goods. This year, we've really come to the rescue.

For the next few days, I'm not offering this cultured pearl necklace at $1,200. I'm not selling it for $300. That's because I don't want to SELL you these pearls at all... I want to *GIVE* them to you. This cultured pearl necklace is yours **FREE**. You pay nothing except basic shipping and processing costs.

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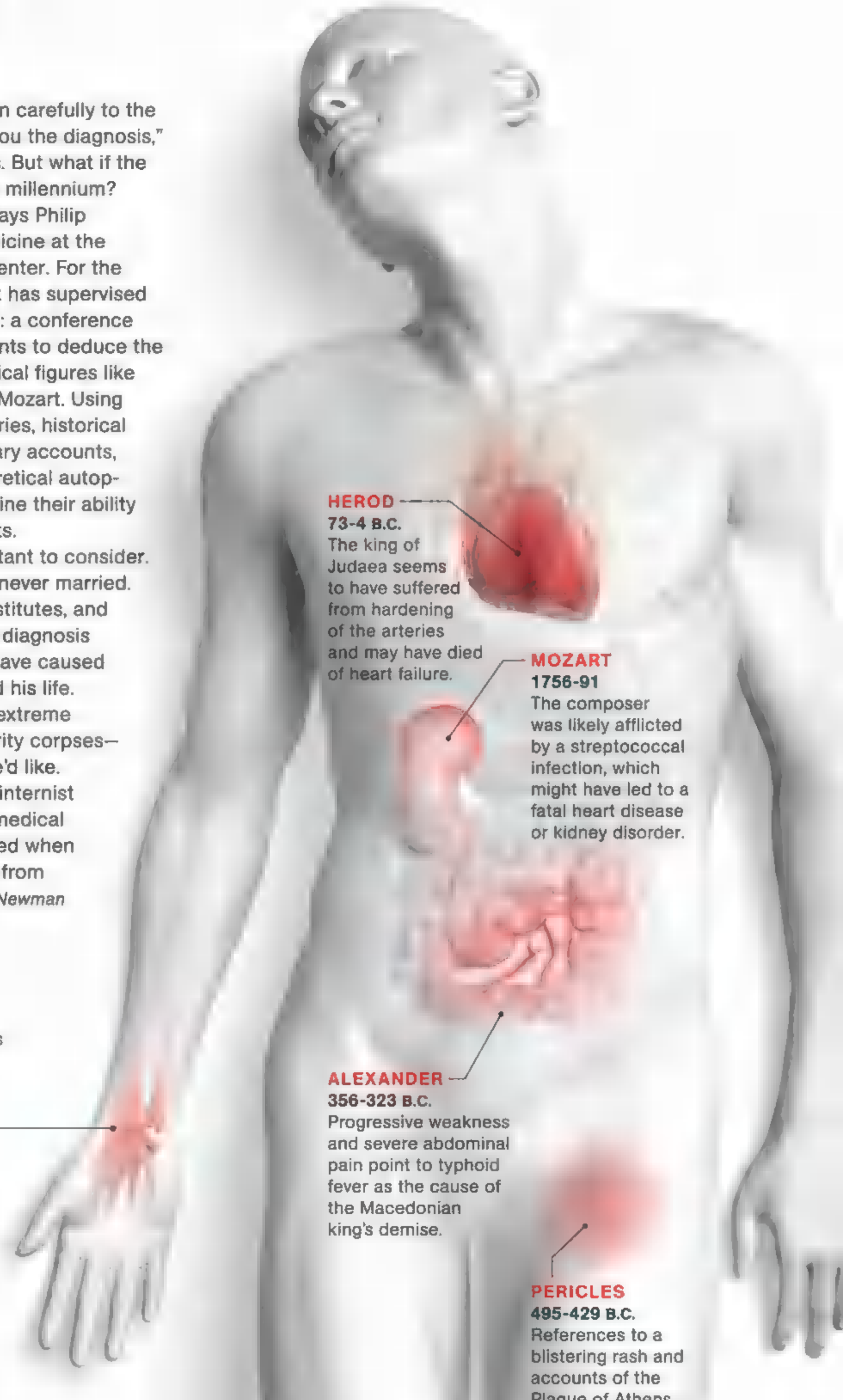
Final Exam "Listen carefully to the patients, and they'll tell you the diagnosis," a medical maxim advises. But what if the patient's been dead for a millennium?

The rule still applies, says Philip Mackowiak, chief of medicine at the Baltimore V.A. Medical Center. For the past 15 years Mackowiak has supervised the ultimate postmortem: a conference that challenges participants to deduce the cause of death for historical figures like Pericles, Columbus, and Mozart. Using evidence drawn from diaries, historical records, and contemporary accounts, presenters perform theoretical autopsies, which help them refine their ability to diagnose living patients.

Social history is important to consider. Beethoven, for instance, never married. His writings mention prostitutes, and that supports a disputed diagnosis of syphilis, which could have caused his deafness and claimed his life.

The cold cases in the extreme also humanize the celebrity corpses—sometimes more than we'd like. Says Faith Fitzgerald, an internist who dissected Mozart's medical history: "We are disquieted when extraordinary people die from ordinary things." *—Cathy Newman*

ABSTRACT AUTOPSIES
Here are five notable figures and the diseases that may have done them in.



ART: BRYAN CHRISTIE DESIGN

See The Bigger Picture

Biodiversity Photo Contest

Renowned National Geographic photographer Joel Sartore brings us face-to-face with biodiversity loss. His photographs of endangered species often give the world a final glimpse of vanishing life.

A world of amazing connections "Biodiversity is beautiful. The spectacular variety of life on Earth keeps our planet healthy and balanced. When I travel the world as a photographer, I see that the intricate connections between all species—from the smallest insects to the largest trees—are fragile and threatened. When we lose species we lose connections and that can trigger chain reactions reaching all the way to you and me. In parts of the world, bees have vanished, so people now have to hand-pollinate fruits and vegetables with feathers. When snake species are lost, mouse populations skyrocket, invading our crops. As chameleons, other reptiles, and amphibians vanish, massive numbers of insects will remain uneaten, many of which carry disease to humans. Trees and other plants that are so invaluable in providing medicines and cleaning our soil, water, and air are disappearing faster than ever before.

The one thing we can't lose is hope. We still have time to turn things around. Our children will inherit a world rich—or poor—in biodiversity based on how much we preserve and protect today. My photos are my way of asking us all to stop, look, and care."

Get your children to stop and look and enter the See The Bigger Picture Photo Contest.

Submit photos, learn more about biodiversity, and see full contest rules at

www.seethebiggerpicture.org

Airbus sees the bigger picture, and works to minimize environmental impact by reducing greenhouse gas emissions, lowering fuel consumption, and creating quieter, more efficient aircraft. Airbus created the first aircraft recycling program of its kind in the world, and earned the ISO 14001 Environmental Certification. Together, Airbus and National Geographic support the UN-backed project, *The Green Wave*, in the world's most far-reaching biodiversity program to children, youth, and families.

THE GREEN WAVE

AIRBUS

For Official Rules visit www.seethebiggerpicture.org. Parent or legal guardian must enter on behalf of child. CONTEST IS VOID WHERE PROHIBITED BY LAW.

New high-nitrate fireworks don't add much smoke to an indoor space.

Friendlier Fire

The EPA is worried about fireworks. It's not so much the noise and smoke—it's the toxic chemical that provides the oxygen needed to burn the fuel.

The culprit is perchlorate, and the fear is it could seep into drinking water. Early research suggests it might hinder the thyroid's production of growth hormones, notably in children and pregnant women. "It deserves more study," says EPA spokesman Rick Wilkin.

After a fireworks blast, bits of perchlorate can land in nearby water. Poor cleanup of duds adds to contamination. And perchlorate lingers. In ■ study of an Oklahoma lake from 2004 to 2006, levels spiked following ■ fireworks show and took 20 to 80 days to stabilize. Why the range? The warmer the water, the faster the perchlorate dissipated.

Chemists Darren Naud and Mike Hiskey have devised ■ solution. Most of the fireworks made by their New Mexico company use cleaner burning, nitrate-based oxidants instead of perchlorate. This low-smoke variety is ideal for indoor shows like Cirque du Soleil, but outdoor venues opt for Chinese imports, which are far cheaper. Without laws regulating perchlorate, event planners aren't likely to spend more bucks for their bang. *—Catherine L. Barker*

PHOTO: DARREN NAUD, DMD SYSTEMS

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ALVIN UPDATES
The famed submersible is getting a makeover.

Video and Lighting
High-definition cameras and LED lights will provide better images.

Thruster
A forward lateral one will make turning sharper, movement easier.

Manipulators
On swivels, the "arms" will be stowed so they do not block the view.

Camera

Air tanks

Batteries
Lithium-ion will replace lead-acid, enabling *Alvin* to stay on the bottom 8 hours instead of 6.

Sample Basket
A stronger version will bear bigger loads.

Personnel Sphere
An 18 percent expansion will offer more room for equipment, passengers.

The deep-sea submersible *Alvin*, built in 1964, was named after Woods Hole engineer and geophysicist Allyn Vine.

Overhauling Alvin It illuminated the *Titanic*, discovered hydrothermal vents on the seafloor, even located a lost hydrogen bomb. Now *Alvin* is ready for a new adventure: a major makeover. After 45 years and 4,500 dives, America's hardest working, deepest descending submersible is slated for its biggest overhaul since 1973. According to Anthony Tarantino of the Woods Hole Oceanographic Institution, which operates the Navy-owned vessel, the upgrades will occur in two phases over several years, as funding permits. Those changes (above) will let the nimble, small-truck-size sub, which transports a pilot and two scientists, do more things better—like dive four miles instead of 2.8, and survey 99 percent of the ocean bottom versus 63. So don't think of it as a midlife crisis; consider it *Alvin 2.0*, retrofitted for 21st-century exploration. *—Jeremy Berlin*

ART: DON FOLEY PHOTO: DAN FORNARI, WOODS HOLE OCEANOGRAPHIC INSTITUTION

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WORLD
MASTERCARD

In utero motion created the elegant scrawl on the grape-size shell of this great-tailed grackle egg.

Exterior Design When it comes to the art of egg decoration, Mother Nature is the original master. The patterns and lines that adorn many eggs—like those of murres, grackles, and jacanas—are positively calligraphic. These markings, which get their pigment from bile acids and broken-down red blood cells, are applied during the tail end of the 20 hours during which the egg is in the shell-gland region of the oviduct. A shell that emerges encircled with wispy streaks (above) means the egg rotated while the inking occurred.

Such surface flourishes serve two practical purposes, offering camouflage from predators and identification for colony-dwelling birds trying to spot their own. Another distinction, says wildlife ecologist Linnea Hall: No other animals on Earth mark their eggs. Now that's original artwork. *—Catherine L. Barker*

PHOTO: JOEL SARTORE AT UNIVERSITY OF NEBRASKA STATE MUSEUM

MENU

INFO

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Beelzebufo ampinga

As big as a slightly deflated beach ball, Madagascar's *Beelzebufo* (top) could have downed baby dinosaurs.

Big Old Frog It was mostly mouth and belly, this amphibious beast from about 65 million years ago. Thick-skulled, ten-pound *Beelzebufo ampinga* ("armored frog from hell") was one of the most massive frogs ever; today's biggest is the seven-pound *Conraua goliath.* The ambush predator lived on Madagascar, where David Krause of Stony Brook University and his team began finding bone bits in 1993. Susan Evans of University College London and others shaped 15 years' worth of fossils (72 fragments in all) into frog form. "When we scaled the bones against modern skulls, we saw just how big this thing could get," Evans says. "It was ■ monster." Many geologists believe Madagascar became geographically isolated some 88 million years ago, but *Beelzebufo*'s closest living kin are in South America. One theory is that the two landmasses remained linked via Antarctica longer than was thought. *—Jennifer S. Holland*

Smallest Frog?

It's a tie. Among living frogs, *Eleutherodactylus iberia* of eastern Cuba (left) and *Brachycephalus didactylus* from Brazil are equally diminutive—making them the smallest frog in the Northern and Southern Hemisphere, respectively. Adults of each species can be tinier than the word "tiny" on this page.

Downsized in more ways than one, small frogs often have fewer toes and teeth than their larger counterparts, and a higher-pitched chirping call (due to pinhead-size vocal cords). Also, miniature frogs may lay one relatively large egg rather than the typical mass of small ones—perhaps because tiny froglets would dry out quickly or fail to find enough speck-size food to survive.

ART: TODD MARSHALL, NGM MAPS. PHOTO: STEVE WINTER, NATIONAL GEOGRAPHIC STOCK

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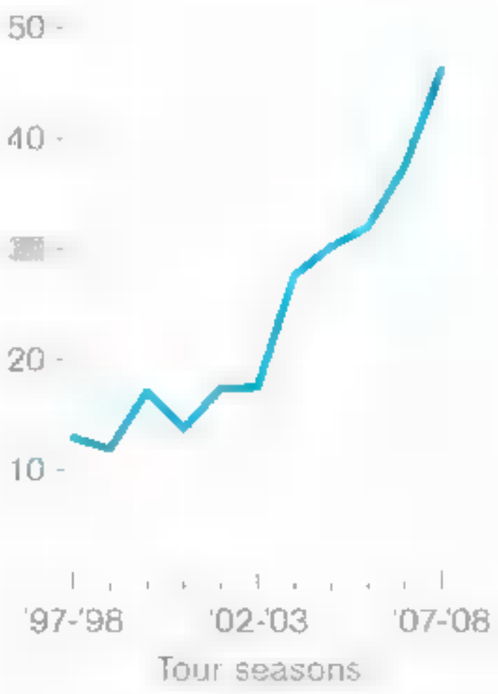
Tourist Sean Farrell dives into 30°F Antarctic waters without a wet suit before swimming—quickly—back to the boat.

SOUTHERN EXPOSURE
Number of tourists visiting Antarctica, in thousands

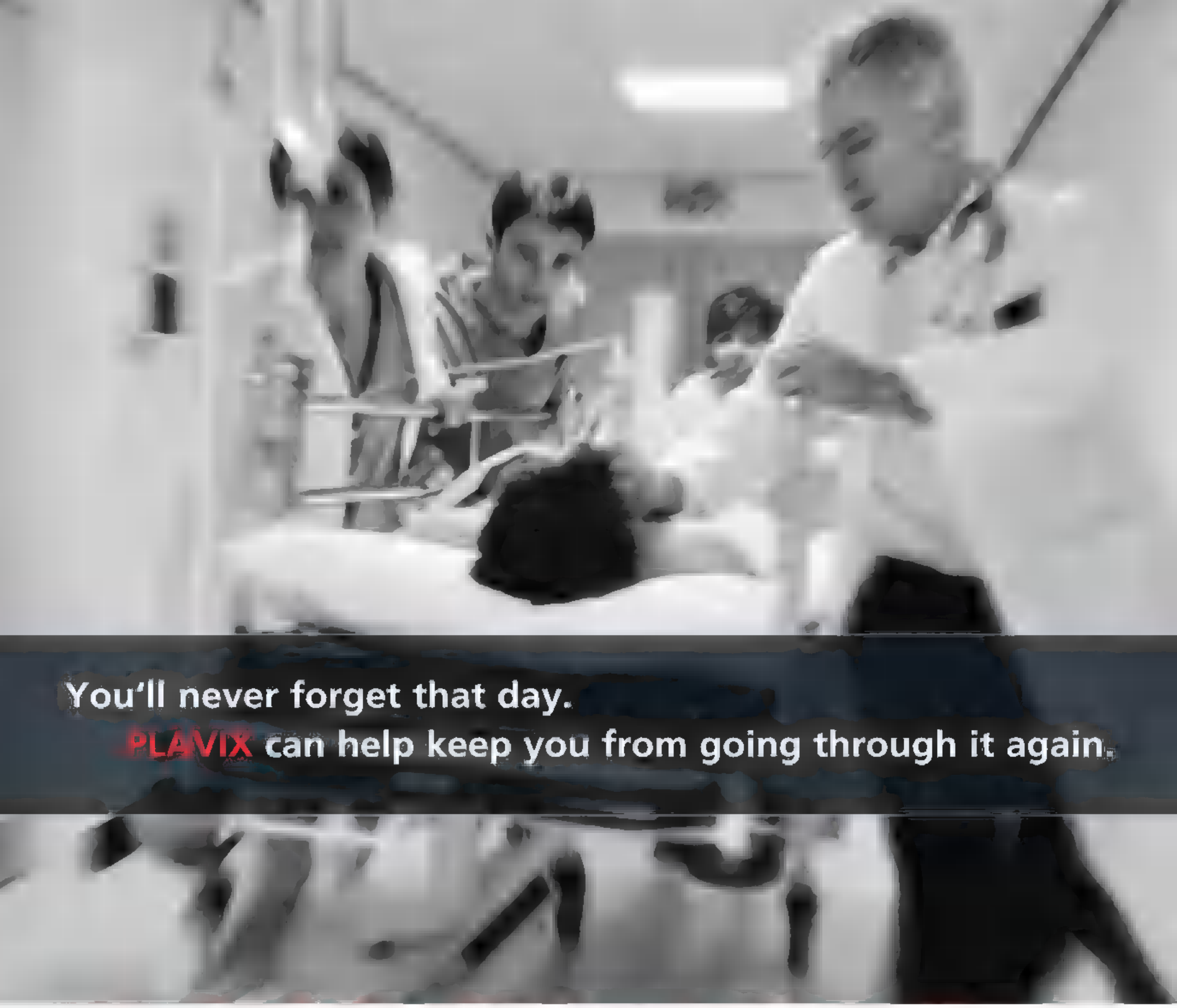


Ice Overflow When Los Angeles attorney Sean Farrell plunged into the numbing ocean off the Antarctic Peninsula in 2007 (above), the view was just what he had hoped: a vast white wilderness. But every few days Farrell, who was on a chartered yacht, spied tourist boats in the distance. A spike in visitors to Antarctica—up 250 percent during the past decade to 46,000—has Farrell wondering if the great white continent wouldn't be better off if he'd stayed home. "Everybody wants to see natural beauty," he says. "But even the most conscientious traveler will have an impact."

So far the tourist industry has policed itself. Guidelines forbid ships with more than 500 passengers from landing on the continent, and groups of more than a hundred from going ashore. But the more ships, the greater the risk to the environment. When the aging vessel *Explorer* sank in 2007, it created ■ mile-long oil slick. Newcomers to the route present problems as well. The latest cruise ships, some carrying more than ■ thousand tourists, aren't strengthened to withstand possible collisions with sea ice.

Environmentalists are calling for laws to curb tourism growth. Through 2010, economic forces may be enough. Visitor numbers will likely flatten as spending slows. *—Karen E. Lange*

PHOTO: PETER MCBRIDE CHART SOURCE: INTERNATIONAL ASSOCIATION OF ANTARCTICA TOUR OPERATORS



PLAVIX can help save lives for those who've had a heart attack caused by a completely blocked artery.

Clots that block off arteries are the main cause of heart attack. And now that you've had a heart attack you are at a greater risk of having another that can be fatal. That's why your doctor may put you on PLAVIX, along with your other heart medicines. Taking PLAVIX with your other heart medicines goes beyond what other heart medicines alone can do to keep blood platelets from sticking together and forming dangerous clots.

IMPORTANT SAFETY INFORMATION: If you have a stomach ulcer or other condition that causes bleeding, you should not use PLAVIX. When taking PLAVIX alone or with some other medicines including aspirin, the risk of bleeding may increase so tell your doctor before planning surgery. And, always talk to your doctor before taking aspirin or other medicines with PLAVIX, especially if you've had a stroke. If you develop fever, unexplained weakness or confusion, tell your doctor promptly as these may be signs of a rare but potentially life-threatening condition called TTP, which has been reported rarely, sometimes in less than 2 weeks after starting therapy. Other rare but serious side effects may occur.

Ask your doctor how PLAVIX can help increase your protection against future heart attack, stroke, and even death.

To learn more about heart attacks and PLAVIX, visit www.plavix.com or call 1-800-230-9202.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

See important product information on the following page.

If you need help paying for prescription medicines, you may be eligible for assistance. Call 1-888-4PPA-NOW (1-888-477-2669), or go to www.pparx.org

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WHO IS PLAVIX FOR?

PLAVIX is a prescription-only medicine that helps keep blood platelets from sticking together and forming clots.

PLAVIX is for patients who have:

- had a recent heart attack.
- had a recent stroke.
- poor circulation in their legs (Peripheral Artery Disease).

PLAVIX in combination with aspirin is for patients hospitalized with:

- heart-related chest pain (unstable angina).
- heart attack.

Doctors may refer to these conditions as ACS (Acute Coronary Syndrome).

Clots can become dangerous when they form inside your arteries. These clots form when blood platelets stick together, forming a blockage within your arteries, restricting blood flow to your heart or brain, causing a heart attack or stroke.

WHO SHOULD NOT TAKE PLAVIX?

You should NOT take PLAVIX if you:

- are allergic to clopidogrel (the active ingredient in PLAVIX).
- have a stomach ulcer
- have another condition that causes bleeding.
- are pregnant or may become pregnant.
- are breast feeding.

WHAT SHOULD I TELL MY DOCTOR BEFORE TAKING PLAVIX?

Before taking PLAVIX, tell your doctor if you're pregnant or are breast feeding or have any of the following:

- gastrointestinal ulcer
- stomach ulcer(s)
- liver problems
- kidney problems
- a history of bleeding conditions

WHAT IMPORTANT INFORMATION SHOULD I KNOW ABOUT PLAVIX?

TTP: A very serious blood condition called TTP (Thrombotic Thrombocytopenic Purpura) has been rarely reported in people taking PLAVIX. TTP is a potentially life-threatening condition that involves low blood platelet and red blood cell levels, and requires urgent referral to a specialist for prompt treatment once a diagnosis is suspected. Warning signs of TTP may include fever, unexplained confusion or weakness (due to a low blood count, what doctors call anemia). To make an accurate diagnosis, your doctor will need to order blood tests. TTP has been reported rarely, sometimes in less than 2 weeks after starting therapy.

Gastrointestinal Bleeding: There is a potential risk of gastrointestinal (stomach and intestine) bleeding when taking PLAVIX. PLAVIX should be used with caution in patients who have lesions that may bleed (such as ulcers), along with patients who take drugs that cause such lesions.

Bleeding: You may bleed more easily and it may take you longer than usual to stop bleeding when you take PLAVIX alone or in combination with aspirin. Report any unusual bleeding to your doctor.

Geriatrics: When taking aspirin with PLAVIX the risk of serious bleeding increases with age in patients 65 and over.

Stroke Patients: If you have had a recent TIA (also known as a mini-stroke) or stroke taking aspirin with PLAVIX has not been shown to be more effective than taking PLAVIX alone, but taking aspirin with PLAVIX has been shown to increase the risk of bleeding compared to taking PLAVIX alone.

Surgery: Inform doctors and dentists well in advance of any surgery that you are taking PLAVIX so they can help you decide whether or not to discontinue your PLAVIX treatment prior to surgery.

WHAT SHOULD I KNOW ABOUT TAKING OTHER MEDICINES WITH PLAVIX?

You should only take aspirin with PLAVIX when directed to do so by your doctor. Certain other medicines should not be taken with PLAVIX. Be sure to tell your doctor about all of your current medications, especially if you are taking the following:

- aspirin
- nonsteroidal anti-inflammatory drugs (NSAIDs)
- warfarin
- heparin

Be sure to tell your doctor if you are taking PLAVIX before starting any new medication.

WHAT ARE THE COMMON SIDE EFFECTS OF PLAVIX?

The most common side effects of PLAVIX include gastrointestinal events (bleeding, abdominal pain, indigestion, diarrhea, and nausea) and rash. This is not a complete list of side effects associated with PLAVIX. Ask your doctor or pharmacist for a complete list.

HOW SHOULD I TAKE PLAVIX?

Only take PLAVIX exactly as prescribed by your doctor. Do not change your dose or stop taking PLAVIX without talking to your doctor first.

PLAVIX should be taken around the same time every day, and it can be taken with or without food. If you miss a day, do not double up on your medication. Just continue your usual dose. If you have any questions about taking your medications, please consult your doctor.

OVERDOSAGE

As with any prescription medicine, it is possible to overdose on PLAVIX. If you think you may have overdosed, immediately call your doctor or Poison Control Center, or go to the nearest emergency room.

FOR MORE INFORMATION

For more information on PLAVIX, call 1-800-633-1610 or visit www.PLAVIX.com. Neither of these resources, nor the information contained here, can take the place of talking to your doctor. Only your doctor knows the specifics of your condition and how PLAVIX fits into your overall therapy. It is therefore important to maintain an ongoing dialogue with your doctor concerning your condition and your treatment.

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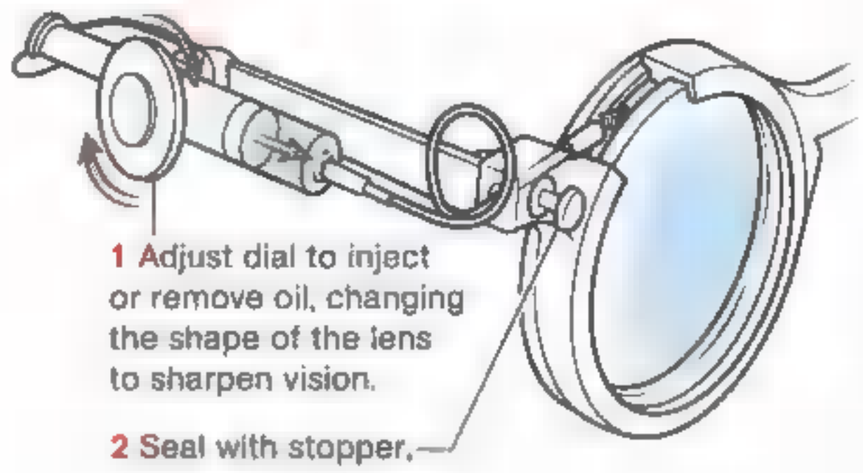
The Eyes Have It More than a billion people in the developing world need glasses. But opticians aren't exactly on every block in sub-Saharan Africa. In some places the ratio is one to one million residents. Pondering this problem, Oxford University physics professor Joshua Silver came up with a brilliantly simple solution: a pair of eyeglasses, currently costing about $19, that the wearer can adjust. Silicone oil is injected into a gap between two sheets of plastic until the lens provides sharp vision (right). The inventor's field research shows the correction can be better than that of prefab glasses sold at ■ store.

As director of the new nonprofit Centre for Vision in the Developing World, Silver envisions a billion pairs on needy eyes by 2020. So far, 30,000 pairs are in use in Africa and eastern Europe, two-thirds distributed through U.S. military aid programs.

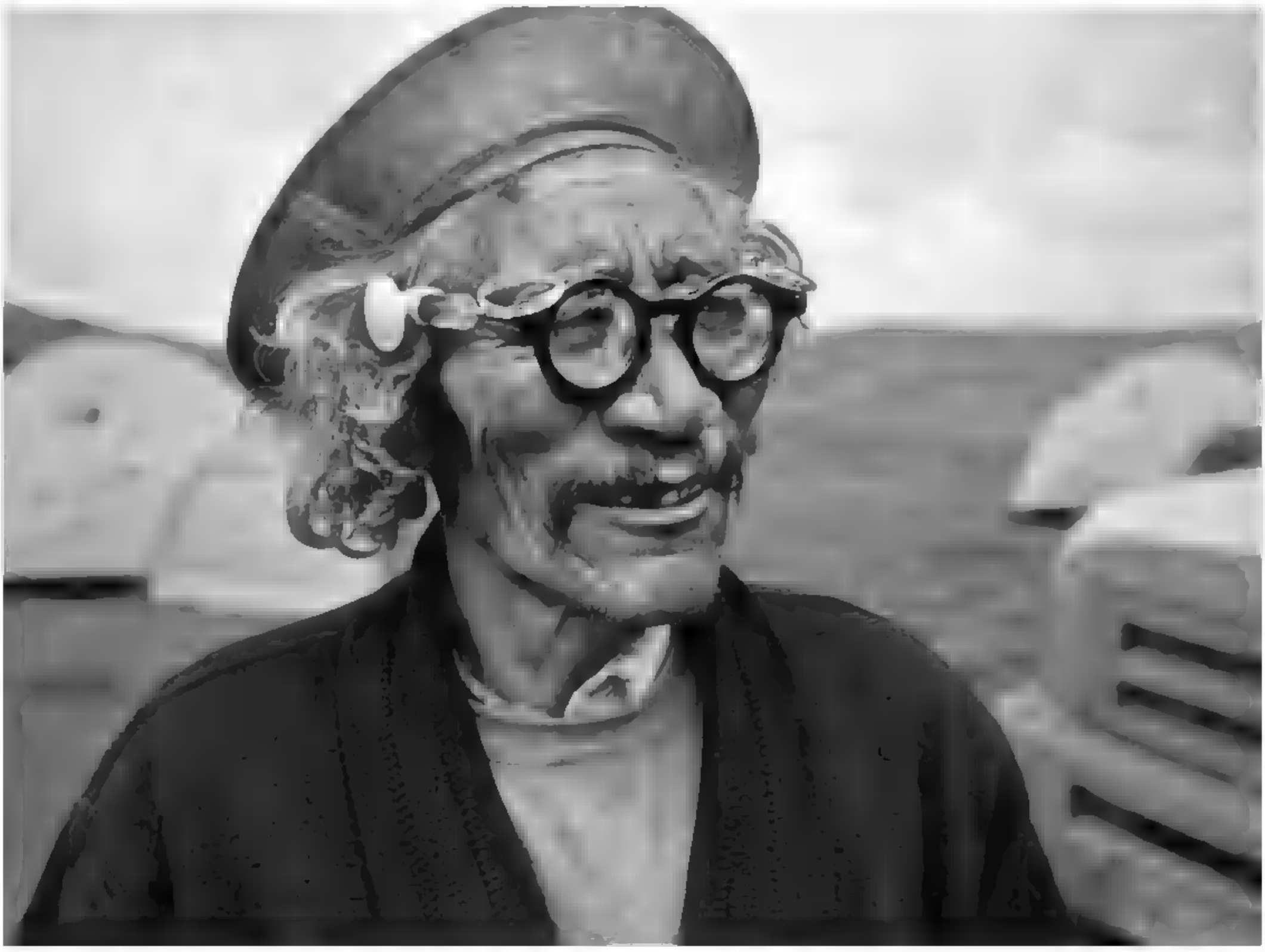
The glasses look ■ bit geeky, but there are few complaints. Silver recalls the first recipient, in Ghana in 1996: a tailor in his 30s whose faltering close vision made it nearly impossible to thread a needle. The tailor adjusted the glasses, threaded the needle on his machine, and began sewing rapidly. "I will not forget that moment," says Silver, "until I entirely lose my memory." *—Marc Silver*

CORRECT YOURSELF
Adaptive eyeglasses can be adjusted for close or distance vision.



1 Adjust dial to inject or remove oil, changing the shape of the lens to sharpen vision.

2 Seal with stopper, then remove tube and syringe.



This man in a remote Tibetan village received his adaptive glasses in 2005.

PHOTO: JOSHUA SILVER
ART: HIRAM HENRIQUEZ, NG STAFF

...on of Khmer civilization, Angkor Wat in Cambodia endures as a revi... religious shrine.

DIVINING ANGKOR

AFTER RISING TO SUBLIME HEIGHTS, THE SACRED CITY MAY HAVE ENGINEERED ITS OWN DOWNFALL.

For local boys the moat at Angkor Wat is a swimming hole. In the 12th century it symbolized the oceans encircling the home of the gods. It also had a practical use: storing water for the city's large population.

FRITZ HOFFMANN

Once viewed solely as a sacred site with a temple in its middle, the five-mile-long West Baray is also understood as a hub of a vast water-management system, crucial to Angkor's wealth and power.

BY RICHARD STONE
PHOTOGRAPHS BY ROBERT CLARK

From the air, the centuries-old temple appears and vanishes like a hallucination. At first it is no more than an umber smudge in the forest canopy of northern Cambodia. Beneath us sprawls the lost city of Angkor, now in ruins and populated mostly by peasant rice farmers. Clusters of Khmer homes, perched on spindly stilts to cope with flooding during the summer monsoon, dot the landscape from the Tonle Sap, the "great lake" of Southeast Asia, some 20 miles to the south, to the Kulen Hills, a ridge jutting from the floodplain a roughly equal distance to the north. Then, as Donald Cooney guides the ultralight plane over the treetops, the magnificent temple comes into view.

Restored in the 1940s, the 12th-century Banteay Samre, devoted to the Hindu god Vishnu, recalls the medieval Khmer Empire at its height. The temple is cloistered inside two sets of concentric square walls. These may once have been surrounded by a moat symbolizing the oceans encircling Mount Meru, mythical home of Hindu gods. Banteay Samre is just one of more than a thousand shrines the Khmer erected in the city of Angkor during a building spree whose scale and ambition rivals the pyramids of Egypt. After we pass, I crane my neck for a last look. The temple has disappeared into the forest.

Angkor is the scene of one of the greatest vanishing acts of all time. The Khmer kingdom lasted from the ninth to the 15th centuries, and at its height dominated a wide swath of Southeast Asia, from Myanmar (Burma) in the west to Vietnam in the east. As many as 750,000 people lived in Angkor, its capital, which sprawled across an area the size of New York City's five boroughs, making it the most extensive urban complex of the preindustrial world. By the late 16th century, when Portuguese missionaries came upon the lotus-shaped towers of Angkor Wat—the most elaborate of the city's temples and the world's largest religious monument—the once resplendent capital of the empire was in its death throes.

Scholars have come up with a long list of suspected causes, including rapacious invaders, a religious change of heart, and a shift to maritime trade that condemned an inland city. It's mostly guesswork: Roughly 1,300 inscriptions survive on temple doorjambs and freestanding stelae, but the people of Angkor left not a single word explaining their kingdom's collapse.

Recent excavations, not of the temples but of the infrastructure that made the vast city possible, are converging on a new answer. Angkor, it appears, was doomed by the very ingenuity that transformed a collection of minor fiefdoms into an empire. The civilization learned how to tame Southeast Asia's seasonal deluges, then faded as its control of water, the most vital of resources, slipped away.

AN INTRIGUING FIRSTHAND ACCOUNT brings the city to life at its zenith. Zhou Daguan, a Chinese diplomat, spent nearly a year in the capital at the end of the 13th century. He lived modestly as a guest of a middle-class family who ate rice using coconut-husk spoons and drank wine made from honey, leaves, or rice. He described a gruesome practice, abandoned not long before his visit, that involved collecting human gall from living donors as a tonic for courage. Religious festivals featured fireworks and boar fighting. The greatest spectacles occurred when the king ventured out among his subjects. Royal processions included elephants and horses decorated with gold, and hundreds of palace women bedecked in flowers.

Lotus flowers and Hindu deities carved in stone mark the holy site of Kbal Spean in the Kulen Hills, the source of two rivers that nourish the Angkor floodplain.

Angkor's daily rhythms also come to life in sculptures that have survived centuries of decay and, more recently, war. Bas-reliefs on temple facades depict everyday scenes—two men hunched over a board game, for instance, and a woman giving birth under a shaded pavilion—and pay homage to the spiritual world inhabited by creatures such as *apsaras,* alluring celestial dancers who served as messengers between humans and the gods.

The bas-reliefs also reveal trouble in paradise. Interspersed with visions of earthly harmony and sublime enlightenment are scenes of war. In one bas-relief, spear-bearing warriors from the neighboring kingdom of Champa are packed stem to stern in a boat crossing the Tonle Sap. The scene is immortalized in stone, of course, because the Khmer were successful in battle.

Although Angkor won that clash, the city was riven by rivalry, which heightened its vulnerability to attacks from Champa to the east and the formidable kingdom of Ayutthaya to the west. Khmer kings had several wives, which blurred the line of succession and resulted in constant intrigue as princes vied for power. "For centuries, it was like the Wars of the Roses. The Khmer state was often unstable," says Roland Fletcher, an archaeologist at the University of Sydney and co-director of a research effort called the Greater Angkor Project.

Some scholars believe that Angkor died the way it lived: by the sword. The annals of Ayutthaya state that warriors from that kingdom "took" Angkor in 1431. No doubt the prosperous Khmer city would have been a rich prize: Inscriptions boast that its temple towers were clad in gold, as Zhou's breathless account confirms. To reconcile tales of Angkor's wealth with

ROYAL PROCESSIONS INCLUDED ELEPHANTS AND HORSES DECORATED WITH GOLD, AND HUNDREDS OF PALACE WOMEN BEDECKED IN FLOWERS.

the dilapidated ruins encountered by Western travelers, French historians a century ago concluded from the tantalizing allusion that Ayutthaya sacked Angkor.

Fletcher, who says his obsession is to "figure out what makes settlements grow and die," is dubious. Some early scholars, he says, viewed Angkor through the lens of the sieges and conquests of European history. "The ruler of Ayutthaya, indeed, says he took Angkor, and he may have taken some formal regalia back to Ayutthaya with him," says Fletcher. But after Angkor was captured, Ayutthaya's ruler installed his son on the throne. "He's not likely to have smashed the place up before giving it to his son."

Court intrigue may not have perturbed most of Angkor's subjects, but religion was central to daily life. Angkor was what anthropologists call a regal-ritual city. Its kings claimed to be the world emperors of Hindu lore and erected temples to themselves. But as Theravada Buddhism gradually eclipsed Hinduism in the 13th and 14th centuries, its tenet of social equality may have threatened Angkor's elite. "It was very subversive, just like Christianity was subversive to the Roman Empire," says Fletcher. "It would have been exceedingly difficult to stop."

Such a religious shift would have eroded royal authority. The regal-ritual city operated on a moneyless economy, relying on tribute and taxation. The kingdom's de facto currency was rice, staple of the conscripted laborers who built the temples and the cast of thousands who ran them. An inscription at one complex, Ta Prohm, notes that 12,640 people serviced that temple alone. The inscription also records that more than 66,000 farmers produced nearly 3,000 tons of rice a year to feed this multitude of priests, dancers, and temple workers. Add just three large temples to the equation—Preah Khan and the larger complexes of Angkor Wat and the Bayon—and the calculated farm labor required swells to 300,000. That's nearly half of the estimated population of Greater Angkor. A new, egalitarian religion such as Theravada Buddhism might have led to rebellion.

Or maybe the royal court simply turned its back on Angkor. Successive rulers had a habit of erecting new temple complexes and letting older ones decay, and that penchant for starting anew might have doomed the city when sea trade began to flourish between Southeast Asia and China. Maybe it was simple economic opportunism that, by the 16th century, had caused the Khmer center of power to shift to a location closer to the Mekong River, near Cambodia's present-day capital, Phnom Penh, affording it easier access to the South China Sea.

Economic and religious turmoil may have hastened Angkor's downfall, but its rulers were blindsided by another foe. Angkor became a medieval powerhouse thanks to a sophisticated system of canals and reservoirs that enabled the city to hoard scarce water in dry months and

Resembling the* apsaras, *the beautiful dancers who appear on many of Angkor's temple walls, 17-year-old Sonsa Ry bends to tradition and washes her husband's feet at their wedding in the village of Thnal Toteung.

disperse excess water during the rainy season. Forces beyond Angkor's control threw this exquisitely tuned machine into disarray.

ONE OF ANGKOR'S HOLIEST SITES is high in the Kulen Hills at the headwaters of two rivers, the Puok and the Siem Reap. Under the shade of gnarled strangler fig trees, submerged in the clear water of a lazy creek, are row after row of circular bumps, each about six inches wide, carved into the dark sandstone riverbed. These are worn lingams, cylindrical stone sculptures representing the essence of the Hindu god Shiva. The lingams lead like a road to another sculpture in the riverbed: a thick-walled square, a yard wide, with a narrow inlet. It's a yoni, a symbol of the Hindu source of life.

Angkor's high priests came here to thank the gods for providing the lifeblood of the kingdom. A short walk upstream is a natural bridge of sandstone that lends this holy site its name, Kbal Spean—Khmer for "bridgehead." Water rushes through a cleft, splashing an adjoining rock face where Vishnu, legs crossed, meditates atop an angry ocean; sprouting from his navel is a lotus-flower-bearing Brahma. Here in the Kulen Hills the ancient gods enjoy perpetual libations from flowing water.

By harnessing the monsoon tide that gushed from the Kulen Hills, *(Continued on page 48)*

Beijing-based writer Richard Stone is Asia editor for Science *magazine. Robert Clark has photographed more than a dozen cover stories for the* Geographic.

FRITZ HOFFMANN

IMPERIAL ANGKOR

ITS VAST WATER SYSTEM WAS A MARVEL OF ENGINEERING—AND A CAUTIONARY TALE OF TECHNOLOGICAL OVERREACH

At its height in the 13th century (depicted in this reconstruction), the capital of the Khmer Empire was the most extensive urban complex in the world. Using imaging radar and other tools, researchers have learned that Greater Angkor covered almost 400 square miles, roughly the area of the five boroughs of New York City, with as many as 750,000 inhabitants. Most were rice farmers and laborers who worked the giant jigsaw of fields. In the city center, perhaps 40,000 people—elites and farmers alike—lived within the walls of Angkor Thom, a 3.5-square-mile enclosure with temples and a royal palace. Though the rainy season usually brought ample water, the ability to store water in great reservoirs called *barays* and control its flow gave Angkor an edge in times of drought or flood. But this engineered landscape required constant maintenance. When the water system faltered, so did Angkor's power.

ANGKOR'S COMPLEX PLUMBING

In Southeast Asia, months of monsoon rains are followed by months of near drought. To ensure a steady water supply, stabilize rice production, and control flooding, Khmer engineers built a network of canals, moats, ponds, and reservoirs. Massive earthworks slowed the wet-season deluge flowing from the Kulen Hills, directing it into canals that fed the barays and temple moats. Spreading across the gently sloping land, the water drained finally into the Tonle Sap, the largest freshwater lake in Southeast Asia.


KULEN HILLS
FOREST
SACRED SOURCE
Angkor's temples. The hills were logged for timber
and firewood and to clear land for farming; deforestation
Kompong Phluk
(modern)

Strangler fig trees and creeping lichens devour ruins at Ta Prohm, once home to hundreds of monks. To build their magnificent complexes, Angkor's feudal rulers relied on revenue generated by rice growing.

Monsoon clouds spill rain into the Srah Srang reservoir. Its guardians included lions and flame-shaped nagas, spirits trusted to bring rain. By the 16th century, power shifted from Angkor toward Phnom Penh after a period of erratic monsoons.

The meditative face [illegible] Victory Gate [illegible] Angkor Thom likely depicts Jayavarman VII, whose [illegible] (1181 to circa 1215) raised Angkor to a peak [illegible] wealth and power. His military successes extended Khmer [illegible] across much [illegible] Southeast [illegible].

Only kings and high priests could worship atop the hill temple of Phnom Bakheng. Now reverent silence reigns only after closing time. Sunset-viewing tourists crowd onto the platform in numbers that cause structural damage

For centuries the coming and going of water has shaped the lives of villagers near Tonle Sap. In early July (above), before the lake rises, houses built on 20-foot stilts stand high and dry in Kompong Phluk.

Come November (right), villagers float instead of walk as the lake, home of one of the world's richest inland fisheries, brims at high water, and families easily net dinner from their porches.

(Continued from page 35) Angkor and its rulers flourished. From the era of Jayavarman II, who laid the kingdom's foundations in the early 800s, the empire's growth depended on bumper rice harvests. Throughout southern Asia, perhaps only the ancient cities of Anuradhapura and Polonnaruwa in Sri Lanka and their famed reservoirs could compare to Angkor's ability to guarantee a steady water supply.

That reliability required massive feats of engineering, including a reservoir called the West Baray that's five miles long and 1.5 miles wide. To build this third and most sophisticated of Angkor's large reservoirs a thousand years ago, as many as 200,000 Khmer workers may have been needed to pile up nearly 16 million cubic yards of soil in embankments 300 feet wide and three stories tall. To this day the rectangular reservoir, or *baray,* is fed by water diverted from the Siem Reap River.

The first scholar to appreciate the scale of Angkor's waterworks was Bernard-Philippe Groslier, an archaeologist with the French School of Asian Studies (EFEO). In a landmark 1979 treatise, he envisioned Angkor as a "hydraulic city." The great barays, he argued, served two purposes: to symbolize the primeval sea of Hindu cosmogony and to irrigate rice fields. Unfortunately, Groslier could not pursue this concept further. Cambodia's civil war, the brutal reign of the Khmer Rouge, and the ouster of the regime by Vietnamese forces in 1979 turned Angkor into a no-go zone for two decades. After Vietnamese troops withdrew, looters descended

on Angkor, swiping statues and even chiseling off bas-reliefs.

When Christophe Pottier, an architect and archaeologist, reopened EFEO's research station at Angkor in 1992, the first priority was helping Cambodia restore dilapidated and pillaged temples. But Pottier was drawn to the wilderness beyond the temple walls. He spent months crisscrossing the southern half of Greater Angkor on motorbike and foot, mapping once hidden house mounds and shrines near artificial ponds called water tanks. (Lingering lawlessness deterred Pottier from surveying the northern half.) Then, in 2000, Fletcher and his colleague Damian Evans laid hands on NASA radar images of Angkor. They were a revelation: The University of Sydney team, working with EFEO and APSARA, the Cambodian agency that manages Angkor, found vestiges of many more settlements, canals, and water tanks, particularly in Angkor's inaccessible areas. Donald Cooney's ultralight flights have helped Fletcher and Pottier, now a co-director of the Greater Angkor Project, examine these features in finer detail. Crucially, they found inlets and outlets to the barays, ending a debate catalyzed by Groslier's work about whether the colossal reservoirs were used solely for religious rituals or for irrigation. The clear answer is both.

The researchers were amazed by the ambition of Angkor's engineers. "We realized that the entire landscape of Greater Angkor is artificial," Fletcher says. Over several centuries, teams of laborers constructed hundreds of miles of

BAS-RELIEFS DEPICT EVERYDAY SCENES—MEN HUNCHED OVER A BOARD GAME, A WOMAN GIVING BIRTH. THEY ALSO REVEAL TROUBLE IN PARADISE.

canals and dikes that relied on subtle differences in the land's natural inclination to divert water from the Puok, Roluos, and Siem Reap Rivers to the barays. During the summer monsoon months, overflow channels bled off excess water. After the rains petered out in October or November, irrigation channels dispensed stored water. The barays may also have helped replenish soil moisture by allowing water to soak into the earth. In surrounding fields surface evaporation would have drawn up the groundwater to supply crops. "It was an incredibly clever system," says Fletcher.

That clever water system may have made the difference between mediocrity and greatness. Much of the kingdom's rice was grown in embanked fields that would otherwise have relied on monsoon rains or the seasonal ebb and flow of water on the Tonle Sap floodplain. Irrigation would have boosted harvests. The system could also have provided survival rations during a poor monsoon season, says Fletcher. And the ability to divert and impound water would have afforded a measure of protection from floods. When other kingdoms in Southeast Asia were struggling to cope with too little or too much water, he says, Angkor's waterworks would have been "a profoundly valuable strategic asset."

Thus Fletcher was baffled when his team unearthed one of the more extraordinary pieces of Angkorian workmanship—a vast structure in the waterworks—and found that it had been demolished, apparently by Angkor's own engineers.

IT'S ALMOST NOON on a June day about ten miles north of Angkor Wat, and even at the bottom of a muddy, 14-foot-long trench, there's no relief from the fierce sun. Fletcher takes off a dark blue baseball cap and wipes his brow. It looks as if the self-possessed researcher is going to launch into a precise explanation of the grayish red stone blocks his team, along with Chhay Rachna of APSARA, has unearthed. Instead, he sighs and says, "This is simply fantastic!"

The stone blocks fitting snugly together were hewed from laterite, a spongy, iron-laden soil that hardens when exposed to air. When Fletcher and Pottier first found a section of the structure a few years ago, they thought it was the remains of a small sluice gate.

"It's turned into a monster," he says. The blocks are the remnants of a spillway across a sloping dam that may have extended as long as a football field. Around the end of the ninth century, with Angkor blossoming, engineers excavated a long canal that altered the course of the Siem Reap River, redirecting it southward to the newly constructed East Baray, a reservoir nearly as big as the later West Baray. The dam, positioned in the river, diverted water to feed the canal. But part of the massive structure may also have functioned as a spillway during monsoon surges, when water would have overtopped the low structure and flowed down the former river channel.

The ruins of the spillway are a vital clue to an epic struggle that unfolded as generations of Khmer engineers coped with a water system that grew ever more complex and unruly. "They probably spent vast portions of their lives fixing it," says Fletcher. Some of the dam's blocks lie in a jumble; huge sections of masonry are missing. "The most logical explanation is that the dam failed," Fletcher says. The river may have chewed into the dam, gradually weakening it. Perhaps it was washed away by an unusually heavy flood, the kind that comes along every century or even every 500 years. The Khmer then ripped apart much of the remaining stonework, salvaging the blocks for other purposes.

Another clue that the water system was failing comes from a pond at the West Mebon, an island temple in the middle of the West Baray. Pollen grains preserved in the muck show that lotuses and other aquatic plants flourished in the baray until the early 13th century. Then new kinds of pollen appear, from species such as ferns that prefer marsh or dry land. Right at Angkor's zenith, one of its reservoirs apparently went dry for a time. "Something was

Society Grant This project was funded in part by your National Geographic Society membership.

Gamblers gather for a cockfight. A crocodile hunts for fish. A war canoe advances. Carvings at the Bayon temple record events large and small from Angkor's past.

going wrong much earlier than we expected," says Daniel Penny, a pollen expert and a co-director of the Greater Angkor Project.

Any deterioration of the waterworks would have left Angkor vulnerable to a natural phenomenon no engineer of that day could have anticipated. Starting in the 1300s, Europe endured a few centuries of unpredictable weather marked by harsh winters and chilly summers. Until recently there was only sketchy information on how other parts of the world fared during this period, called the Little Ice Age. Now it appears that Southeast Asia, too, experienced climatic upheaval.

Around Angkor, the summer monsoon season lasts from roughly May through October and delivers nearly 90 percent of the region's yearly precipitation. A dependable monsoon is critical for all manner of life, including people. To unmask monsoon patterns of long ago, Brendan Buckley of the Lamont-Doherty Earth Observatory in Palisades, New York, ventured into the forests of Southeast Asia in search of trees with annual growth rings. He and his team knew it would not be easy: Most species in the region lack distinguishable growth rings or have ones that aren't laid down year by year. Several forays paid off with a clutch of long-lived species, including teak and *po mu,* a rare cypress. Some po mu trees they cataloged are nine centuries old, survivors of both Angkor's heyday and its demise.

The po mu trees told a stunning story. Sets of constricted growth rings showed that the trees had endured back-to-back megadroughts, from 1362 to 1392 and from 1415 to 1440. During these periods the monsoon was weak or delayed, and in some years it may

Dynasties rise and fall but fish and rice are constants in Khmer daily life. As floodwaters ebb from a paddy field near Angkor Wat, Lao Lan sizes up his catch at a fish barrier. Not enough to sell, he says, but enough to eat.

[illegible] HOFFMAN

ANGKOR, IT APPEARS, WAS DOOMED BY THE VERY INGENUITY THAT TRANSFORMED A COLLECTION OF MINOR FIEFDOMS INTO AN EMPIRE.

have failed completely. In other years, mega-monsoons lashed the region.

To a tottering kingdom, extreme weather could have been the coup de grâce. Decades earlier, Angkor's waterworks were already ailing, to judge from the idled West Baray. "We don't know why the water system was operating below capacity—it's a conundrum," says Penny. "But what it means is that Angkor really had no fat to burn. The city was more exposed to the threat of drought than at any other time in its history." Prolonged and severe droughts, punctuated by torrential downpours, "would have ruined the water system," says Fletcher.

Still, Penny says, "we're not talking about the place becoming a desert." People on the Tonle Sap floodplain south of the main temples would have been buffered from the worst effects. The Tonle Sap is fed by the Mekong River, whose headwaters in Tibetan glacier fields would have been largely immune to the effects of an altered monsoon. But Khmer engineers, skilled as they were, could not alleviate parched conditions in the north by moving Tonle Sap water against the lay of the land. Gravity was their only pump.

If inhabitants of northern Angkor were starving while other parts of the city were hoarding rice, the stage would have been set for severe unrest. "When populations in tropical countries exceed the carrying capacity of the land, real trouble begins," says Yale University anthropologist Michael Coe. "This inevitably leads to cultural collapse." A malnourished army, preoccupied with internal strife, would have exposed the city to attack. Indeed, Ayutthaya's invasion and the Khmer king's ouster happened near the end of the second megadrought.

Add to the climate chaos the shifting political and religious winds already buffeting the kingdom, and Angkor's fate was sealed, says Fletcher. "The world around Angkor was changing. Society was moving on. It would have been a surprise if Angkor persisted."

The Khmer Empire was not the first civilization felled by climate catastrophe. Centuries earlier, as Angkor was rising, halfway around the world a similar loss of environmental equilibrium was hammering the Maya city-states in Mexico and Central America. Many scholars now believe that the Maya succumbed to overpopulation and environmental degradation following a series of three punishing droughts in the ninth century. "Essentially, the same thing happened to Angkor," says Coe, who in the 1950s was the first to discern similarities between the Khmer and Maya civilizations.

Modern societies may need to brace for similar climatic challenges. According to Buckley, the most likely trigger of the Angkor megadroughts was intense and persistent El Niño warming of the surface waters of the central and eastern tropical Pacific Ocean. Scientists debate whether human-caused climate change will lead to more pronounced El Niños, but the Vietnamese tree rings show that even natural oscillations in the Pacific can spark catastrophe.

Angkor's end is a sobering lesson in the limits of human ingenuity. The Khmer had transformed their world—a monumental investment that would have been excruciating for the kingdom's rulers to forsake. "Angkor's hydraulic system was an amazing machine, a wonderful mechanism for regulating the world," Fletcher says. Its engineers managed to keep the civilization's signal achievement running for six centuries—until, in the end, a greater force overwhelmed them. □

A woman named Pronh Kin receives a water blessing poured by a monk to bring luck and health. Such benedictions served kings and commoners alike in the glory days of Angkor.

Learn how long-ago canals and reservoirs might have kept water flowing. See *Secrets of Angkor* on the **National Geographic Channel, July 14 at 9 p.m. ET in the U.S.**

Fly over Angkor Wat—and dive down for a closer look—at **ngm.com.**

FRITZ HOFFMANN

FEEDING

When tide and current turn a tiny bay into a bowl of plankton, manta rays in the Maldives gather for a roiling, whirling feast.

Like an aquatic vacuum cleaner, a manta thrusts forward to capture plankton. Frontal cephalic fins channel water into the mouth, where plankton are trapped in sieves of spongy tissue between riblike gill rakers.

BY BRUCE BARCOTT

PHOTOGRAPHS BY THOMAS P. PESCHAK

Four hundred forty miles off the southern coast of India, in the archipelago nation of the Maldives, there is an uninhabited island named Hanifaru. It's not much to see from the air: a spray of tropical shrubs on what appears to be a truckload of sand. Hanifaru is so small a child could walk its entire scimitar-shaped coastline in a ten-minute stroll. The island's size isn't unusual for the Maldives, a collection of 1,192 tiny islands clumped in 26 atolls encompassed by the vastness of the Indian Ocean. But several times a year, when time and tide align, manta rays from throughout the Maldives converge here to feed in a spectacular coral-reef ballet.

From May through November, when the lunar tide pushes against the Indian Ocean's southwestern monsoon current, a suction effect pulls tropical krill and other plankton from deep water up to the surface. The current sweeps the krill into the cul-de-sac of Hanifaru Bay. If the krill stayed at the surface, they'd wash over the bay's coral walls and out to the safety of the open sea. But they can't. Instinct forces them to dive away from daylight. When they do, they get trapped deep in the bowl. In just a few hours a massive concentration of plankton builds up, a swarm so thick it turns the water cloudy.

Cue *Manta birostris.* "Just after high tide you'll see a few manta rays turn up," says Guy Stevens, a British marine biologist who's been researching the Maldives mantas for the past three years. "Then *poof,* a whole group will move in, and you'll get as many as 200 feeding for two to four hours in a bay no bigger than a soccer field."

These massive fish (the wingspans of Maldives mantas can reach 12 feet) are dynamic filter feeders, shoveling their shoe-box mouths through krill like threshers through wheat, inhaling prey. They barrel roll when they hit a rich patch, somersaulting backward to stay in the hot spot. They chain feed, following each other in a train of open maws.

In the tight confines of Hanifaru Bay, mantas must expand their repertoire, and Stevens has identified maneuvers rarely seen by scientists. When 50 or more fish chain feed in the bay, something extraordinary happens. The head of the line catches the tail, and the chain spins into a vortex. "We call that cyclone feeding," says Stevens. "When you get more than a hundred mantas doing that, they start to spiral out. When the chain breaks down, you get chaos feeding." The stately dance in the milky waters turns into a free-for-all, with hundreds of mantas bumping into each other. Adding to the confusion are whale sharks—languid, plankton-eating giants, each about the size of a 40-foot shipping container—that show up to share the spoils. Within hours the plankton run out, the feast winds down, and the mantas plow the bay's sandy bottom with their cephalic fins to throw hidden prey back into the water column.

Generations ago those hornlike cephalic fins earned mantas the name devilfish. Their terrifying size and bat shape fed an aura of mystery and menace, and mantas were vilified as ferocious monsters. That changed in the 1970s, when scuba divers found mantas to be gentle creatures. Sometimes they even permitted humans to catch joyrides on their broad backs.

Because of their accommodating nature, mantas today have achieved the dubious status of dive-tourism attractions, luring humans to swim with them in closer-than-optimum quarters. For a species considered near threatened, however, this newfound popularity could literally be a lifesaver. Mantas, with their slow reproductive rate, are vulnerable to overfishing, so a robust tourist trade could give local communities an economic incentive to conserve the fish rather than kill them. It's a delicate balance, though—too many humans could drive mantas out of feeding grounds like Hanifaru Bay.

To avoid that, Stevens has proposed turning the bay into a marine sanctuary. A new Maldives president has vowed to strengthen the archipelago's marine protections, but his government has so far been slow to respond to Stevens's idea. "I'm not ruling out declaring Hanifaru a

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Bruce Barcott covered the wildlife of Svalbard, Norway, in our April issue. Thomas Peschak is chief photographer for the Save Our Seas Foundation.

The elongated scoop of Hanifaru Bay (above) collects plankton, mantas, and flocks of tourists who come to swim with mantas. Guy Stevens, a biologist with the Save Our Seas Foundation, worries that crowds, and lax enforcement of marine-protection laws, threaten the fish's safety.

marine-life sanctuary. But we need to increase our ability to enforce existing environmental laws before creating new protected areas," says Environment Minister Mohamed Aslam.

Meanwhile, scientific knowledge about mantas remains surprisingly thin. Only last year a leading expert proposed splitting the species in two: smaller resident mantas, like those in the Maldives that remain near shore, and larger transient mantas (with wingspans as great as 22 feet) that roam the world's tropical and semitropical oceans. And researchers are just beginning to learn more about those cephalic fins. "When you approach a manta, it will unroll a cephalic fin and wave it back and forth as if it's scanning," says Robert Rubin, a California-based marine biologist who's studied mantas in Mexico for 20 years. "Mantas are essentially flat sharks, and we know some sharks have electrical receptors in their faces. The hypothesis is that mantas use those fins to pick up electrical signals from other animals moving in the water."

In the Maldives, Stevens continues to catalog the local animals. (He's identified more than 1,500 individuals by their unique spot patterns.) His data also record the exact timing of the feedings, information that would be of great value to the local guide industry. Stevens hears the clock ticking, and he is scrambling to organize a self-policing regime among resorts and local guides before dive tourists overrun Hanifaru. "We don't want to ruin what we've got here," he says. If his plan works, Hanifaru Bay will remain a sanctuary for cyclone-feeding manta rays, with just enough room for whale sharks, and humans as well. □

LISA R. RITTER, NG STAFF; CAITLIN SARGENT
SATELLITE IMAGE: DIGITALGLOBE

Mantas and whale sharks commonly feed together (left), untroubled by the occasional collision. As many as 200 rays and a half dozen whale sharks have been counted in a period of several hours, Stevens reports. When the plankton soup turns thin, mantas work the sandy bottom (above) with their cephalic fins to stir any hidden prey up into the water column.

As plankton swarms accumulate, mantas come to feast. The total Maldives population is estimated at 10,000 individuals. Three are following one behind another, chain feeding (at left). These mantas may soon swirl into a spiral formation for cyclone feeding—behavior rarely seen outside of Hanifaru Bay.

ROOMFULS OF TOTAL STRANGERS UNDER

MASS HYPNOSIS!

THE WORLD'S LARGEST AND MOST POLITE

CORN DOG CHOMP!

FARM ADOLESCENTS WELL VERSED IN

ANIMAL HUSBANDRY!

MOTHERS WHO LOOK LIKE DAUGHTERS

AND VICE VERSA!

CANDY APPLES, PORK CHOPS ON A STICK, AND

FRIED COCA-COLA!

YOUNG MEN WHO WANT YOU TO BECOME A

CAREER BEAUTICIAN!

TAKE IN THE STATE FAIR WITH

GARRISON KEILLOR

PHOTOGRAPHS BY

JOEL SARTORE

Sabra Jackson and her calf Princess took honors at the Indiana State Fair


SUPER A

"I ain't got no body," croons Andy Mullins, midway barker at the State Fair of Texas. "I greet people, crack 'half' jokes, sing 'All of Me,'" he says. But the mirror illusion that makes him look like half a man is the big draw. "I love the way kids look at me and ask if I'm real.

Eating into history, 8,400 Iowa fairgoers bite in synchrony at the first-ever Corn Dog Chomp, in 2008. Recipes vary (bacon fat makes some extra tasty), but corn dogs have been fair fare since at least the 1940s. A new treat debuted in Texas in 2006: fried Coca-Cola (batter balls flavored with cola syrup).


781
456

THE STATE FAIR is a ritual carnival marking the end of summer and gardens and apple orchards and the start of school and higher algebra and the imposition of strict rules and what we in the north call the Long Dark Time. Like gardening, the fair doesn't change all that much. The big wheel whirls and the girls squeal and the bratwursts cook on the little steel rollers and the boys slouch around and keep checking their hair. It isn't the World's Columbian Exposition, the Aquarian Exposition, the Great Exhibition of the Works of Industry of All Nations, the Exposition Universelle, the Gathering of the Tribes, or the Aspen Institute. It's just us, taking a break from digging potatoes.

The Ten Chief Joys of the State Fair are:

1. To eat food with your two hands.

2. To feel extreme centrifugal force reshaping your face and jowls as you are flung or whirled turbulently and you experience that intense joyfulness that is indistinguishable from anguish, or (as you get older) to observe other persons in extreme centrifugal situations.

3. To mingle, merge, mill, jostle gently, and flock together with throngs, swarms, mobs, and multitudes of persons slight or hefty, punky or preppy, young or ancient, wandering through the hubbub and amplified razzmatazz and raw neon and clouds of wiener steam in search of some elusive thing, nobody is sure exactly what.

4. To witness the stupidity of others, their gluttony and low-grade obsessions, their poor manners and slack-jawed, mouth-breathing, pop-eyed yahootude, and feel rather sophisticated by comparison.

5. To see the art of salesmanship, of barking, hustling, touting, and see how effectively it works on others and not on cool you.

6. To see designer chickens, the largest swine, teams of mighty draft horses, llamas, rare breeds of geese, geckos, poisonous snakes, a two-headed calf, a 650-pound man, and whatever else appeals to the keen, inquiring mind.

7. To watch the judging of livestock.

8. To observe entertainers attempt to engage a crowd that is moving laterally.

9. To sit down and rest amid the turmoil and reconsider the meaning of life.

10. To turn away from food and amusement and crass pleasure and to resolve to live on a higher plane from now on.

THE MIDWEST is State Fair Central, and it thrives here because we are the breadbasket of America, Hog Butcher, Machinemaker, Stacker of Particleboard, Player With Chain Saws, Land of the Big Haunches. And also because Midwesterners are insular, industrious, abstemious, introspective people skittish about body contact, and a state fair is liberation from all of that, a plunge into the pool of self-indulgence, starting with a thick pork chop hot off the grill and served on a stick with a band of crisp brown fat along one side. The fat is not good for you. You eat the pork chop, fat and all, and your child eats her pork chop, and then you score a giant vanilla shake from the Dairy Bar to cushion the fall of a bagful of tiny doughnuts. Now you're warmed up and ready to move on to the corn dog course.

But first here is a flume ride your child is agitating for, so you climb onto a steel raft and plunge into a concrete gorge and over a waterfall, and a two-foot wave washes over the gunwales, and now your pants are soaked. You disembark. You look like a man who could not contain his excitement. For cover, you hide in the crowd. You walk close behind people. You join the throng at the hot-corn stand and comfort yourself with a salty ear of buttered corn. Your pants chafe. You wander among booths of merchandise looking for men's pants and find

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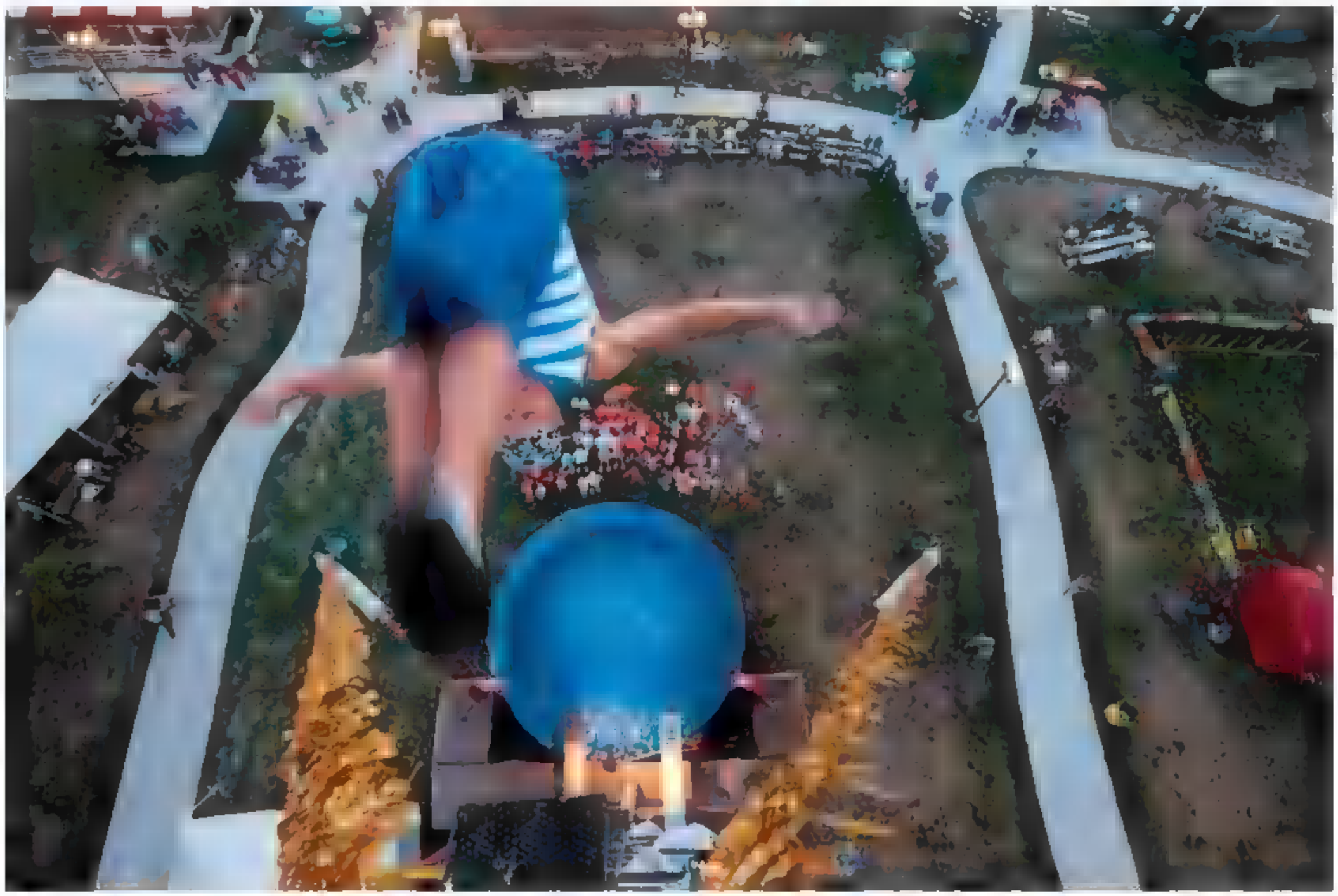
Garrison Keillor's Rhubarb Tour visited six state fairs in 2008. Meanwhile, photographer Joel Sartore energized his coverage with at least 30 corn dogs.



Lou Plocher's double somersault with a half twist into eight feet of water, from 80 feet up, leaves Nebraskans gasping. Here he's a funnyman in pirate garb, but some days he dives while on fire. After thousands of plunges and two broken feet, he says, "it's still a rush."

encyclopedias, storm windows, lawn mowers, vegetable peelers and choppers, humidifiers, log splitters, and home saunas. Your search for dry pants leads you through buildings where champion jams and jellies are displayed on tables draped with purple, blue, red, yellow ribbons, and also champion cakes (angel food, Bundt light, Bundt dark, chiffon, chocolate, chocolate chiffon, German chocolate, jelly roll, pound, spice, sponge, vegetable, or fruit) and pickles (beet, bean, bread-and-butter, cucumber sweet, dill without garlic, dill with garlic, peppers sweet, peppers hot, watermelon). And through an education pavilion where headhunters lie in wait for you to pause and make eye contact, and they leap on you and make you hear about the benefits of beautician training, the opportunities in the field of broadcasting.

The way to dry out your pants is to get on a motorized contraption that whirls you through the air. Your child suggests you ride the giant Slingshot that is across the street. A long line of dead-end kids wait to be strapped into a cage and flung straight up in the air. The mob of onlookers waiting for the big whoosh looks like the crowds that once gathered to watch public executions.

You pass up the Slingshot for the double Ferris wheel. An excellent clothes dryer, lifting you up above the honky-tonk, a nice breeze in your pants, in a series of parabolas, and at the apex you look out across the gaudy uproar and the blinking lights, and then you zoom down for a close-up of a passing gang of farm boys in green letter jackets and then back up in the air. You tell your child that this Ferris wheel is the ride that, going back to childhood, you always saved for last, and so riding it fills you with nostalgia. She pats your hand. "You'll be all right, Dad,"

☛ THE YOUNG PEOPLE LEADING COWS AROUND THE SHOW RING ARE RELATIVES OF ABRAHAM AND JOB. YOU COULD LEARN SOMETHING FROM THEM.

she says. After ten minutes you come down nice and dry, and also the food has settled in your stomach, and you're ready for seconds.

OF THE TEN JOYS, the one that we Midwesterners are loath to cop to is number three, the mingling and jostling, ■ pleasure that Google and Facebook can't provide. American life tends more and more to put you in front of a computer screen in a cubicle, then into a car and head you toward home in the suburbs, where you drive directly into the garage and step into your kitchen without brushing elbows with anybody. People seem to want this, as opposed to urban tumult and squalor. But we have needs we can't admit, and one is to be in a scrum of thinly clad corpulence milling in brilliant sun in front of the deep-fried-ice-cream stand and feel the brush of wings, hip bumps, hands touching your arm ("Oh, excuse me!"), the heat of humanity with its many smells (citrus deodorant, sweat and musk, bouquet of beer, hair oil, stale cigar, methane), the solid, big-rump bodies of Brueghel peasants all around you like dogs in a pack, and you—yes, elegant you of the refined taste and the commitment to the arts—are one of these dogs. All your life you dreamed of attaining swanhood or equinity, but your fellow dogs know better. They sniff you and turn away, satisfied.

Some state fairs are roomier, some gaudier, but there is a great sameness to them, just as there is a similarity among Catholic churches. No state fair can be called trendy, luxurious, dreamy—none of that. Nothing that is farm oriented or pigcentric is even remotely upscale.

Wealth and social status aren't so evident at the fair. The tattooed carnies who run the rides have a certain hauteur, and of course if you're on horseback, you're aristocracy, but otherwise not. There is no first-class line, no concierge section roped off in the barns. The wine selection is white, red, pink, and fizzy. Nobody flaunts his money.

The state fair, at heart, is an agricultural expo, and farming isn't about getting rich, and farmers discuss annual income less than they practice nude meditation on beaches. Farming is about work and about there being a Right Way and a Wrong Way to do it. You sit in the bleachers by the show ring and see this by the way the young women and men lead their immaculate cows clockwise around the grumpy, baggy-pants judge in the center. They walk at the cow's left shoulder, hand on the halter, and keep the animal's head up, always presenting a clear profile to the judge's gaze, and when he motions them to get in line, the exhibitors stand facing their cows and keep them squared away.

You and I may have no relatives left in farming, and our memory of the farm, if we have any, may be faint, but the livestock judging is meaningful to us—husbandry is what we do, even if we call it education or health care or management. Sport is a seductive metaphor (life as a game in which we gain victory through hard work, discipline, and visualizing success), but the older metaphor of farming (life as hard labor that is subject to weather and quirks of blind fate and may return no reward whatsoever and don't be surprised) is still in our blood, especially those of us raised on holy scripture. The young men and women leading cows around the show ring are relatives of Abraham and Job and the faithful father of the prodigal son. They subscribe to the Love Thy Neighbor doctrine. They know about late-summer hailstorms. You could learn something from these people.

TWILIGHT FALLS on the fairgrounds, and a person just suddenly gets sick of it all. You've spent hours gratifying yourself on deep-fried cheese curds, deep-fried ice cream, testing one sausage against another, washing them down with authentic American sarsaparilla, sampling your child's onion rings, postponing the honey sundae for later, and now it is later, and the horticulture building and the honey-sundae booth are four blocks and a river of humanity away. You and the child stand at the entrance to the midway, barkers barking at you to try the ring-toss, shoot a basketball, squirt the water in the clown's mouth and see the ponies run, win the teddy bear, but you don't want to win a big blue plush teddy bear. You have no use for one whatsoever. There is enough inertia in your life as

Like mother, like daughter. The Look-alike Contest is an Iowa fair Rural Americana Olde Tyme event. Pairs are judged not just on matching faces but also voice, walk, and mannerisms. Pair 239 (at far right) took second; 251, sixth. Top prize: A blue ribbon, five bucks, and bragging rights.

it is. And now you feel the great joy of revulsion at the fair and its shallow pleasures, its cheap tinsel, its greasy food. You are slightly ashamed of your own intake of animal fats. Bleaugh, you think. Arghhhh. OMG. You have gone twice to ATMs to finance this binge, and you regret that. No more of this! You take the child's hand. There will be no honey sundae tonight, honey. We got all that out of our system. We are going home and sober up and get busy.

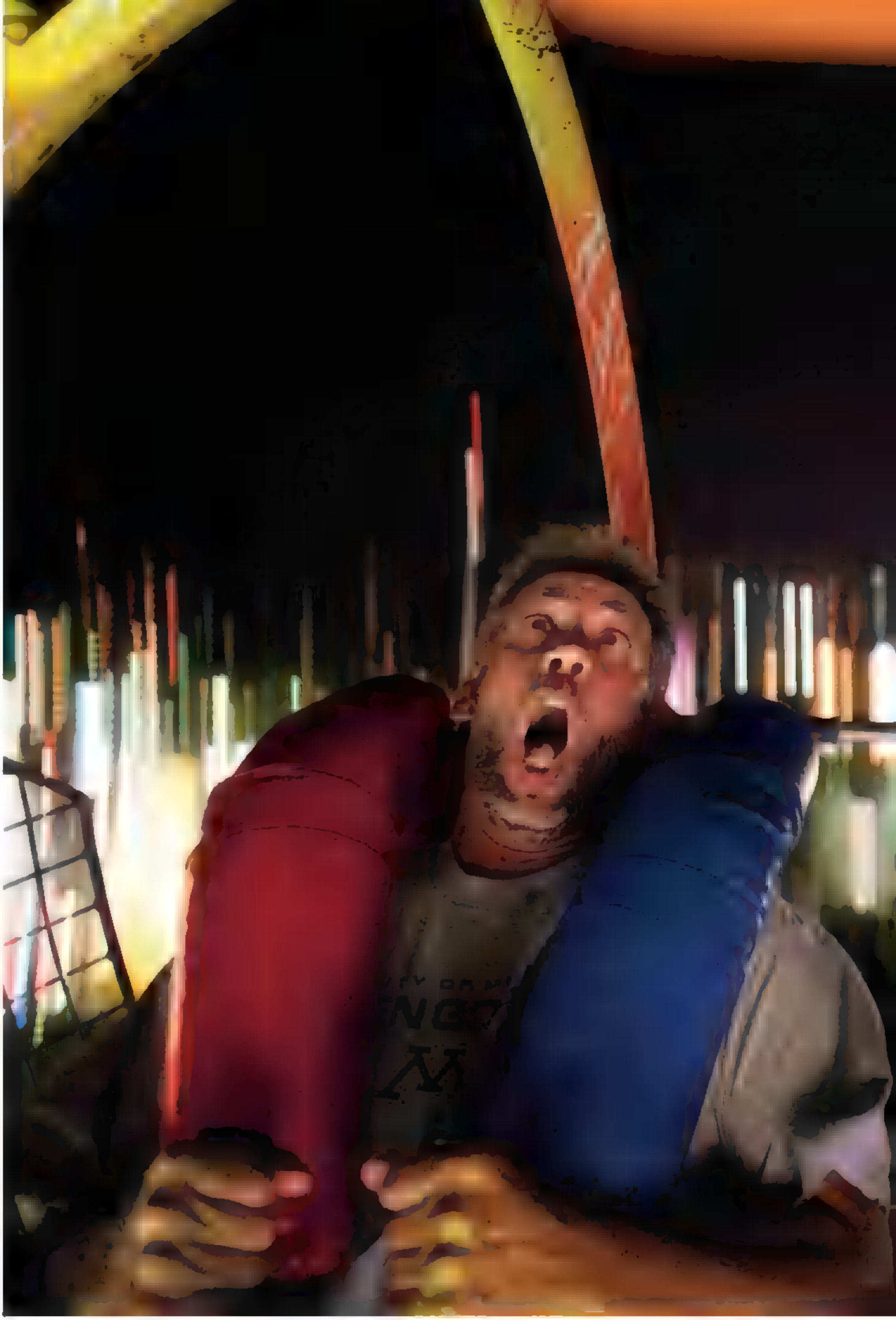
You hike toward where you recollect you parked your car this morning, and by a stroke of God's grace you actually find it, and your child does not have to watch a father roaming around pitifully, moaning to himself. You get in, and you drive back to the world that means something, the world of work. The Long Dark Time is coming, and you must gather your herds to shelter and lay in carrots and potatoes in the cellar.

The fair is gone the next day, the rides disassembled, the concessions boarded up, the streets swept clean. Dry leaves blow across the racing oval, brown squirrels den up in the ticket booths, the midway marquee sways in the wind. You drive past the fairgrounds a few days later on your way to work. It looks like the encampment of an invading army that got what booty it wanted and went home. And now you are yourself again, ambitious, disciplined, frugal, walking briskly, head held high, and nobody would ever associate you with that shameless person stuffing his face with bratwurst and kraut, mustard on his upper lip, and a half-eaten deep-fried Snickers in his other hand. That was not the real you. This is. This soldier of the simple declarative sentence. You have no need for cheap glitter and pig fat and pointless twirling. You have work to do. Onward. □

Some 470 hoofed entrants paraded by judges during Minnesota's 4-H dairy cattle show in 2008, with seven major breeds competing in more than a dozen age groups. Points for qualities such as udder fullness, body angularity, and stride add up to coveted awards.

Fun for all ages! Minnesota sisters Bridgit and Bergen Flom (above) sport big rainbow dos styled for $14 each and a buck for glitter. Iowa's derby stunts (below) are always a blast: Gregory "Dr. Danger" Carpenter performed the Suicide Car Jump—a 50-foot, 60 mile-an-hour leap from a flaming ramp into a four-stack of junked cars—38 times last year, with three hospital trips and no life or health insurance. Despite cracked bones and burns, "I squeak by each time," he says.

Indiana has Madagascar hissing roaches (above) that pull tiny tractors bearing flags of rival universities without a whit of training, brags Purdue University roach wrangler Tom Turpin. And who can resist group hypnosis? Iowa volunteers go catatonic (below) at the snap of hypnotist Ron Diamond's fingers. Next he may tell them to wiggle or scratch. "I create an environment that lets the subconscious work, then make suggestions," Diamond says. "The mind does wonderful things, if we let it."



When you're slammed through the night sky at 75 miles an hour and 4 g's, "your stomach stays on the ground," says Minnesota fairgoer Tim Petersen. Reluctant at first, he and Deborah Smith finally succumbed to the Slingshot's 200-foot launch and free fall to Earth. Go again? "Definitely."

Between Fire & Ice

Entrusted to the people of New Zealand by a Māori chief, Mount Ngauruhoe's snow-shrouded volcanic peak guards an epic landscape of forests, barrens, and craters.

Ice

Enter the otherworld of *The Lord of the Rings* in New Zealand's Tongariro National Park. 83

A volcanic boulder rests above Upper Tama lake, a crater below Mount Ngauruhoe. The volcano has exploded more than 70 times since 1839. Throughout the park, officials urge visitors to know likely paths of volcanic mudflows and to leave when eruption threatens.

BY MEL WHITE
PHOTOGRAPHS BY STUART FRANKLIN

As you contemplate the heart of
Tongariro National Park—
three peaks that rise in one of
the most beautiful places in the
famously beautiful country of New Zealand—

you may well find questions of aesthetics intruding on your appreciation of the spectacular scene before you.

To the south looms the craggy mass of Ruapehu, at 9,176 feet the tallest peak on the North Island. Built by 250,000 years of volcanism, it's still active today—waking every few years to send up enormous columns of steam and ash. To the north is Tongariro, even older, a sprawling complex of ancient craters where vents continuously and ominously exhale sulfurous clouds.

In the middle stands Ngauruhoe. Less massive than its companions, Ngauruhoe (Mount Doom in Peter Jackson's *Lord of the Rings* film trilogy) forms a wondrously symmetrical cone, capturing your attention with the simple perfection of its form. The mountain lacks only a few streaks of vivid red crayon above it to be every child's drawing of the archetypal volcano.

What (you ask yourself) is this anomalously sensual shape doing in such a rough neighborhood? And further: What does it mean that you're so irresistibly attracted to it?

"Age, I do abhor thee; youth, I do adore thee," the Bard wrote, and there you have it—an explanation and a justification, if you need one. This peak was born just a couple thousand years ago. The Ice Age glaciation that tore and scarred Ruapehu and Tongariro happened long before Ngauruhoe was born. Rain and fiery explosions have not yet marred its face. In the geological world, too, the beauty of youth works its seductive power.

The Maori, New Zealand's indigenous people, look on all three volcanoes with awe and consider them *tapu,* a word whose diverse meanings include both "sacred" and "sanctity." When Europeans began settling the central North Island in the mid to late 19th century, dividing the land into towns and farms, the Maori feared for the integrity of the peaks. The paramount chief, Horonuku, or Te Heuheu Tukino IV, came up with a farsighted solution: He transferred the volcanoes' tapu from himself to Queen Victoria, and in 1887 he entrusted the mountains and the land within a mile of their summits to the government and people of New Zealand. The tract became the country's first national park and has grown to the current 194,270-acre protected area.

Mel White's last story was "Path of the Jaguar," in March 2009. Stuart Franklin is currently working on projects in the United Kingdom.

Oxidized iron and volcanic debris surround one of the Emerald Lakes on Mount Tongariro. Visitors swim in the park's mineral-tinted lakes, in spite of the water's sulfurous scent.

Maori tapu explains why Tongariro holds the rare distinction of having twice been named a World Heritage site, both for its physical features and, later, for its cultural importance. The park's fire-and-ice combination of active volcanoes and glaciers easily won it the natural-heritage status of sites such as the Great Barrier Reef and the Everglades. But the United Nations committee that decides such matters originally turned down New Zealand's proposal to accept Tongariro as a cultural site, having previously given that rank only to human-built sites (think of Chartres Cathedral and the Egyptian pyramids). After a new presentation from a delegation including Maori elders, though, Tongariro in 1993 became the first site in the world to receive heritage status under a new criterion called associative cultural landscapes, for the terrain's spiritual importance to indigenous people.

THE 12-MILE-LONG TRAIL called the Tongariro Alpine Crossing begins in tussock grassland, then climbs past lava cliffs and glacial moraines (heaps of debris piled up by former glaciers) to the base of Ngauruhoe, where hikers willing to endure a couple of hours trudging up scree can make a side trip to the top of the volcano. The main route ascends the slopes of Tongariro to the top of Red Crater. Steaming like the gate to hell, Red Crater is named for the rock around its mouth, given a chestnut hue by oxidized iron. Surrounding swaths of black lava testify to the crater's long history of eruptions, continuing through the late 1800s.

On the downslope from Red Crater, three lakes fill explosion pits stained by minerals in shades of emerald that gave them the Maori name Ngarotopounamu. Soon after, the crossing passes another lake, Te Wai-whakaata-o-te Rangihiroa, or Blue Lake. Indeed, on a clear day its water seems torn from the sky above. The trail then descends grassy hillsides and passes steaming volcanic vents to finish in dense forest along a tumbling stream called Mangatipua.

On the southwestern slope of Ruapehu, ancient woodlands of a different sort survive by a quirk of geography. The great bulk of Ruapehu sheltered this forest from the massive Taupo volcano blast of A.D. 186, while trees for miles in all other

LORDS OF THE RING OF FIRE

Tongariro lies on the Ring of Fire—the dynamic seismic zone that encircles the Pacific Ocean. Just off the North Island of New Zealand, one tectonic plate dives beneath another at a subduction zone (below), their clash helping fuel the fires of the three active volcanoes that consume and rebuild the park. These daunting summits and the surrounding eruption-blasted terrain served as director Peter Jackson's realm of evil darkness in his *Lord of the Rings* films. Guidebooks leading movie fans to landscapes featured in the trilogy have become major nonfiction best sellers in New Zealand, as "Middle Earth" tourism adds to Tongariro's allure.

directions were flattened. An easy trail winds under soaring rimu, matai, and kahikatea trees laden with ferns, while below, tree ferns spread their lacework fronds, and kamahi trees seem to be frozen in the throes of a hula-like dance.

This lushness, like Tongariro's innumerable rocky streams and waterfalls, is fed by clouds that drift from the Tasman Sea to release their moisture against the mountain slopes. In the North Island's highlands you'll have ample opportunity to perfect your own definitions of fog, mist, drizzle, sprinkle, light rain, and rain, and the subtle distinctions among them.

COEXISTING WITH TONGARIRO'S BEAUTY are serious conservation and cultural issues. Like the rest of New Zealand, the park's ecosystem suffered terrible losses from the introduction of alien species, from rats brought by the earliest Maori to rabbits, stoats, Australian possums, and cats brought by Europeans. Native birds, which evolved without mammalian predators for millions of years, were devastated and survive today at only a fraction of their former numbers. Even as the kiwi, the bizarre, flightless bird, became the beloved symbol of New Zealand, it almost died out in the wild, its eggs and young devoured by stoats.

Plants, too, cause problems for park managers. An early ranger introduced grouse from Britain as game and brought heather to feed them. The grouse died out, but heather spread as a lavender-hued plague, displacing native vegetation over wide areas. Lodgepole pine came from North America as a timber tree; its wind-borne seeds carry far beyond plantations, making it exceedingly difficult to eradicate.

Only the widespread use of traps and poisons to fight intruders has prevented the decline of species such as the rare blue duck, which still inhabits Tongariro streams; the parrot known by the Maori name *kaka;* and the absurdly fearless little New Zealand robin, which hops around the boots of hikers, searching for insects in leaves stirred by their footsteps. Thanks to intensive poisoning and a program of raising chicks in captivity until they can defend themselves, the kiwi's eerie whistling calls still echo through Tongariro's woodlands, thrilling those who venture out along trails on quiet nights.

Incongruously, the North Island's most popular ski areas sit on the three slopes of Ruapehu, with their associated shops, lifts, and roads. No such blatantly commercial development would be allowed in a national park today, but the ski runs date from 1913 and, for better or worse, attract a half million visitors a season. Department of Conservation (DOC) staffers constantly try to find compromises in park management that will keep skiers satisfied while protecting one of the planet's most wondrous places.

Decisions about Tongariro's safekeeping have grown ever more complex. In recent decades Tongariro's Maori neighbors, the indigenous *iwi* (Maori communities)—long excluded from such matters by the ruling Pakeha (people of European ancestry)—have regained political rights and influence. Some believe that Te Heuheu—who was, after all, chief only of the Ngati Tuwharetoa tribe—had no right to give away the three volcanic peaks on behalf of all Maori and would like to reclaim the park as sacred tribal land. Others, less radical, would close the mountaintops to climbers or restrict access to those accompanied by a local Maori guide.

Bird-eating stoats, parking-lot construction, profound spiritual and cultural values—all these issues crowd the desks of DOC managers. And one more: Theoretically at least, the park could blow itself to smithereens at any moment.

A visitor can put these concerns out of mind for a while—long enough for a hike that in a single day can encompass barren volcanic rock and rich, complex forest, the sound of waterfalls and the whoosh of native pigeons' wings, the smells of sulfur from deep underground and of moss and ferns and earth after rain. And above it all, the sight of the three great peaks of Ruapehu, Ngauruhoe, and Tongariro, the creators and destroyers of this land. □

Tongariro holds the distinction of having twice been named a World Heritage site, both for its physical features and its cultural importance.

Like the rest of New Zealand, the park's
ecosystem suffered terrible losses
from the introduction of alien species.

Emerald Lakes stairstep up Tongariro's infernal slopes, in cool contrast to the steaming, cinder-strewn terrain. Some 65,000 visitors hike the 12-mile Tongariro Alpine Crossing each year.

PANORAMA COMPOSED OF THREE IMAGES

Tranquil beech forests cloak Waitonga Falls as it tumbles 128 feet down the southern flank of Mount Ruapehu. Because the park's volcanoes stand fully exposed to the Tasman Sea, westerly winds wrap around their summits, bringing heavy rainfall. Water cascades down nearly every gully and gorge, seeking the Central Plateau or the sea. National symbol of New Zealand, tree ferns can grow to 20 feet, catching the mist on graceful fronds (above).

This lushness, like Tongariro's innumerable rocky streams and waterfalls, is **fed by clouds** that drift from the Tasman Sea.

Mantled in winter white, 9,176-foot-tall Mount Ruapehu (foreground) reigns over Tongariro National Park. Conical Ngauruhoe and broad Tongariro beyond shed their snow cover when summer comes, but the cold lock on Ruapehu never breaks, making Crater Lake one of the most active volcanic crater lakes perpetually surrounded by snow and ice in the world.

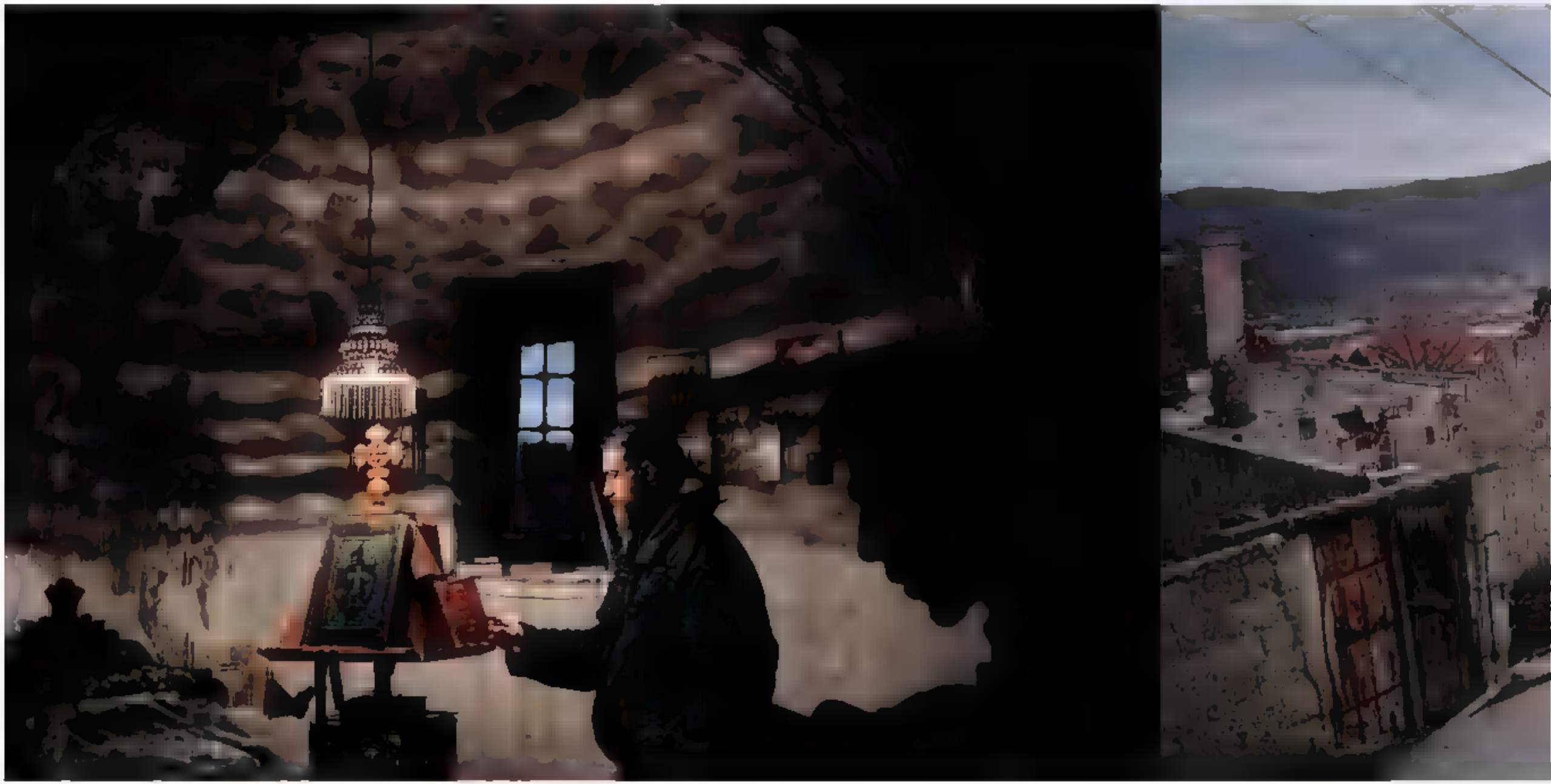

SPAIN

ONE NATION DIVISIBLE

THE SERBS

Right-wing nationalist Serbs march in B
s charged with war crimes. Today's Ser
to unite their scattered people and a de

Harvest is often still brought in by hand in rural Serbia (left). Once the dominant republic in socialist Yugoslavia, Serbia retains an unbroken tradition of family farming because, unlike most communist lands, it largely escaped collectivization. Housing blocks sprout grey and tall in New Belgrade (above), a district of the capital built up after World War II to handle an increasingly urban population.



As dawn creeps over Velika Hoca in Kosovo, ■ young monk (left) recites the Serbian Orthodox liturgy in a chapel graced by fragments of medieval icons. Kosovo's Albanian majority declared independence from Serbia in 2008. Both nationalities argue the land is rightfully theirs. In ethnically split Mitrovica, French peacekeepers (above) fight boredom near homes ruined in interethnic conflict.

BY CHRIS CARROLL PHOTOGRAPHS BY CHRISTOPHER ANDERSON

IN THE ISOLATED VILLAGE of Velika Hoca in southwestern Kosovo—a new nation or a rebellious province of Serbia, depending on whom you ask—people still talk about a brawl that broke out several years ago. It was after the Kosovo war, which had begun between separatist Albanian guerrillas and Serbian forces and had ended when NATO air strikes pounded Serbia and its strongman president, Slobodan Milosevic, into submission in June 1999. The West had stepped in to stop atrocities against Kosovo Albanians and avert a refugee crisis, assuming peace would reign once the dictator and his fighters were vanquished.

But the postwar reality fell short of peace. The majority Albanians were now on top, with the minority Serbs shoved to the bottom. Killings of civilians continued. And a new stream of refugees, Serbian this time, flowed from mountainous Kosovo, a region of endemic ethnic strife and economic stagnation smaller than metro Los Angeles.

On the day of the brawl in Velika Hoca, where a few hundred Serbs hunkered down in a valley between rocky hills, a local politician and former soldier named Bojan Nakalamic—stocky, swaggering, not yet 30 years old—struck a blow for Serbian pride. There's little enough of it left in this land Serbs call their ancient heartland.

As the story goes, several Albanian youths entered the village and began paying too much attention to some local girls. The day ended with the Albanians properly humbled and ejected from the Serbian redoubt, and it was Bojan Nakalamic who led the beating. To the people of Velika Hoca, it proved Serbs could still produce a champion, a man to fear. To me, each retelling made Nakalamic sound more like a nationalistic thug.

So it was a surprise when I finally met him to learn—in a classic, mind-bending Balkan reversal—that this tough guy who bashed Albanians for crossing cultural lines has sided with them politically, joining their new government and defying Serbia's in the process. Supporting Albanian nationalism is not Nakalamic's aim. As a member of a beaten people in a hostile land, though, he has concluded that withdrawing inside a Serbian ghetto spells doom. He told me in careful English, "If we want to survive in Kosovo, we have to participate."

THE FLAG OF THE Serbian Orthodox Church, a guardian of Serbian singularity throughout centuries of struggle, carries the motto "Only Unity Will Save the Serbs." It flies over a people as deeply marked by the past as any can be. Wars and the whims of conquering empires have dispersed the Serbs, who number over ten million, southward to pockets in Kosovo (where 125,000 remain) and Montenegro; throughout central Serbia, where most live today; north to Hungary; and west across Bosnia and Herzegovina and Croatia. (Many others have dispersed to Western Europe and North America.) For centuries they have striven with epic fervor to unite their scattered people, define their lands, preserve their unique identity.

But unity is a quest that has brought the Serbs into harsh conflict with their neighbors in the Balkan ethnic patchwork and with the wider world. Today they are often viewed as the primary aggressors in the bloody wars of the 1990s that dismembered Yugoslavia. With many implicated in crimes against humanity—including ethnic cleansing and genocide in the war in Bosnia—Serbs heatedly protest that the West singles them out for special vilification while overlooking similar crimes perpetrated against them. They face a vexing question: What can Serbian unity mean in 21st-century Europe?

The question is as divisive for the Serbs as it is unsettling for their neighbors. To Nakalamic, the answer begins with taking care of his own village. So he has accepted a seat as the lone Serb on the Rahovec (Orahovac) municipal council, which oversees local villages, including Velika Hoca. The council answers to the Republic of Kosovo, the nine-tenths Albanian country that declared independence from Serbia in February 2008, with strong support from the United

Dragan Tanic (at right) is a Bosnian Serb. His wife, Sanja, is of mixed Muslim-Croat ancestry. They worry about raising a family in war-torn Bosnia and Herzegovina, where schoolchildren are divided into separate religion and history classes by ethnicity. "If we have children," Sanja asks, "where will they fit in?"

FOR CENTURIES SERBS have striven with epic fervor to unite their scattered people, define their lands, preserve their unique identity.

States and most of Europe. To many Serbs, that makes Nakalamic a traitor.

After Kosovo grabbed independence, TV viewers worldwide watched radical nationalists storm through Belgrade, Serbia's capital, smashing windows and torching a symbol of arrogant foreign meddling—the U.S. Embassy. The Serbian government views Kosovo's independence as an illegal dismemberment of Serbia's sovereign territory. It ordered Serbs in Kosovo—many of whom receive cash assistance from Serbia—to boycott elections there, and most obeyed. Without the requisite ballots from his district, Nakalamic lacks a council vote and thus can't fully participate in drafting budgets or ordinances.

Yet many Serbs seem resigned to the new borders, and to the prospect of a smaller, tamer Serbia at ease with its neighbors. "People are marching and demonstrating, but no one really believes we will get Kosovo back," said Marina Alavanja, a young woman I met in Belgrade as she and her fiancé, a Caribbean American from New York, had a midnight drink with friends on a stylish Belgrade street. Alavanja, a student in Florence, is the kind of liberal, internationally oriented Serb on whom Western governments pin their hopes. After Kosovo independence and the resulting riots, Serbian voters, in the spring of 2008, surprised the world by propelling into power a pro–European Union government that vowed to track down Serbian war criminals—evidence of a widespread belief that the country's best hope for cultural and economic growth is with the West.

But outsiders should never mistake resignation for acceptance, says Alavanja. "It's Serbian pride," she says. "We can't say, 'Sure, take Kosovo. Do whatever you want to us.' What kind of people would we be?" Srdja Popovic, a human rights lawyer who pursues accused Serbian war criminals, says the gulf between unreconstructed nationalists and Western-style Democrats, including Serbia's president, Boris Tadic, is not as wide as outsiders may think. To Popovic, all major parties to some extent cling to the ideal of uniting Serbian-inhabited lands—a catalyst for war in the 1990s. "It's charitable to say this country is divided between democrats and nationalists," he says. "In reality, the nationalist ideal rules."

So does an obsession with the past, which for Serbs is a narrative of national suffering and valor. "Small peoples are often the victims of injustice," reflects Dragoljub Micunovic, an opposition figure during the Milosevic years and now a high-ranking Democrat. Micunovic cites the 1908 annexation of Bosnia (home to many Serbs) by Austria-Hungary. Though outraged, Serbia was forced to accede. But in 1914 Bosnian Serb Gavrilo Princip struck back, assassinating the Austrian crown prince in Sarajevo and sparking World War I. Half of Serbia's military-age male population may have died in the war, but the offending empire was obliterated, and in today's Serbia, Princip is a hero.

Ground zero for Serbian martyrdom is now Kosovo. To right-wing Serbs, politicians like the Democrats who decline to battle for it tooth and nail are Judases. The slur's religious imagery is intentional, for many Serbs regard Kosovo as their spiritual heartland. Slobodan Milosevic exploited this sentiment in the 1980s. He rose to the presidency partly on the platform of crushing Albanian power in Kosovo and died in 2006, during his marathon trial for war crimes that included violence against Kosovo Albanian civilians. It is difficult to judge whether the lingering aura of his propaganda offensive or authentic cultural veneration is what moves some Serbs to call Kosovo their Jerusalem, and some their Golgotha.

ON THE HILL west of Velika Hoca, below an observation post manned for nearly a decade by NATO peacekeepers, is a graveyard with a panoramic view: Along with clusters of old houses and hillside vineyards that supply the town's winery, owned by the Serbian Orthodox monastery, more than a dozen tiny churches pepper the valley. Some are medieval treasures adorned

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Chris Carroll is a staff writer for National Geographic. *Christopher Anderson's book about Venezuela,* Capitolio, *will be out this month.*

with ancient frescoes of the life of Christ, icons of saints, the Last Judgment. No one, including the local priest, can explain why this unassuming agricultural place came over the centuries to be invested with such a weight of the sacred.

Some of the village churches, Bojan Nakalamic says, were built during the reign of King Stefan Dusan in the 14th century. The greatest ruler the Serbs ever had, he built a Serbian empire larger than any before or since. Kosovo was at its center when Dusan dubbed himself "Emperor and Autocrat of the Serbs and Greeks, the Bulgarians and the Albanians."

Chuckling, but with his hand on his heart, Nakalamic says: "Outside, I'm a small Kosovo politician. But inside, I'm Dusan."

Only a few decades after Dusan's death, in 1389, an army of perhaps 25,000 Serbs met a superior Ottoman force on Kosovo Field and went down in what many Serbs regard as glorious defeat. Serbia withered in the face of the expanding Ottoman Empire, which erased the country from the map within little more than a century. But the Battle of Kosovo lived on in Serbian literature and song as a symbol of the struggle against foreign domination.

Serbia regained independence in the 19th century and retook Kosovo in the 20th, during the collapse of the Ottoman Empire. Yet several centuries of Turkish domination had not only shaped the Serbs' sense of persecution, but also scattered them across the western Balkans. At

JEROME N. COOKSON AND MARGUERITE M. HUNSIKER, NG STAFF

A crowded Belgrade trolleybus glides past the shattered Yugoslav Army Headquarters, hit by NATO air strikes during the 1999 Kosovo war. Though polls show strong support for joining the European Union, everyday sights like this prompt many Serbs to question their country's recent tilt westward.

Crosstown rivalry flares toward riot during a contest between Belgrade soccer foes Partizan and Red Star. Police mass outside. Serbia's restive young are called a lost generation—their options severely constrained in a country politically and economically isolated since the 1990s.

IMPLICATED IN CRIMES against humanity, Serbs protest that the West singles them out for vilification, overlooking similar crimes perpetrated against them.

the close of the 20th century, the tides of history turned again with the collapse of Yugoslavia. Many of the descendants of those who had fled Ottoman rule came surging back, adding a new chapter to the story of Serbian suffering.

THE SUFFERING INFLICTED by Serbs, however, is what the world remembers most vividly. In the old Turkish market section of the Bosnian capital, Sarajevo, a man named Dragan Tanic grabbed my arm and spun me toward the hills looming to the south. "If you stood here for ten seconds on the wrong day during the war—*poof*." He tapped me in the middle of the chest to indicate I had just been killed by a sniper. "The Serb on the mountain kills you. Normal day in Sarajevo."

The slight twist, which those familiar with Slavic given names might have guessed, is that Tanic is himself a Serb. Like several thousand other Bosnian Serbs around Sarajevo, Tanic took up arms against the Serb forces that laid siege to the city soon after Bosnia declared independence from Yugoslavia in 1992. Under the circumstances, religious heritage mattered less than who was shooting at him. "They were attacking my home, and if someone attacks my home, I defend it."

But he was in the minority. Other Bosnian Serbs—unwilling to live in a country where Bosnian Muslims, or Bosniaks, would dominate—elected to fight Bosnian independence. They controlled the arsenal of the Yugoslav People's Army and overran 70 percent of Bosnia in the first months of the war, forcing non-Serbian populations out of the land they conquered. The order of the day was to clean the territory of large, troublesome minority populations unsuitable for inclusion in a unified Serbia.

Late in the war, ethnic cleansing would lapse into simple slaughter around the eastern Bosnian town of Srebrenica. There Bosnian Serb forces killed perhaps 7,000 mostly civilian Bosniak men and boys—lining some up and shooting them, hunting others down as they tried to escape. It was the bloodiest single episode in Europe since the close of World War II—the first instance of genocide in Europe since the Holocaust, the International Court of Justice ruled.

Srebrenica was a defining event in the modern history of the Serbs. Although the court later ruled that Serbia itself was not directly implicated, the Bosnian Serbs who carried it out had helped cast all Serbs as bloodthirsty killers—damaging national interests, perhaps, more than any of their enemies could.

When the war ended in 1995, and the four-year siege of Sarajevo soon after that, Bosnia was left more or less cleanly divided between ethnic groups. Today, though most people get along in a fashion, ethnic leaders continually squabble. Bosniak politicians inveigh against Serb separatism and war criminals who still run free, while leaders of the Serbs—37 percent of Bosnia's population—tweak Bosniaks with rhetoric about secession. In the capital, most Serbs have decamped for Serb-controlled parts of Bosnia, while Bosniaks have flowed in the opposite direction. Sarajevo retains a patina of multiethnicity—Tanic and his Muslim-Croat wife, Sanja, are an example. But in reality, today it is a mostly homogeneous Muslim city, unlike the one Dragan Tanic remembers from childhood.

At a café on lively Ferhadija Street, just steps from places where scores of civilians were eviscerated by Serb shelling during the war, Tanic said: "I grew up just around the corner, where my mother still lives. But I can sit here for two hours and see no one I know."

HIGH ABOVE THE confluence of the Danube and Sava Rivers in Belgrade, the massive Kalemegdan Fortress guards a hill where Roman soldiers camped. Later, foreign empires that ruled this land used the castle as a border outpost. Below are the shabby-elegant streets of Belgrade's Old City—sprinkled with buildings still in ruins from attacks by NATO warplanes during the Kosovo war a decade ago. To the west across the Sava is New Belgrade, a faceless, sprawling urban grid thrown up after World War II. And on the city's outskirts is a leafy, peaceful little camp—a former communist youth center—that houses

Serb refugees who fled the new countries born during Yugoslavia's disintegration.

One is Maritsa Stula, a small, serene woman in her mid-50s with a distant smile. Her home was Osijek, a Croatian city a hundred miles northwest of Belgrade, in a region where, centuries ago, Austrian rulers gave land and religious freedom to Serbs fleeing Ottoman rule if they agreed to guard the military boundary against the Turks. By the 1970s, when Stula began building a family in Osijek, both empires were long extinct, but more than 600,000 Orthodox Serbs lived in Roman Catholic Croatia—making up some 14 percent of the population.

In those days, Stula says, no one cared who was a Croat and who was a Serb. Yugoslavia was strong and prosperous, President-for-life Marshal Tito still held power in his able hands, and all Yugoslavs were equal.

So she found it incomprehensible that her neighbors should listen when, in the waning days of Tito's rule, the trumpets of nationalism began blowing in Belgrade and the Croatian capital, Zagreb. Serbs spoke of how Nazi-allied Croats had confined them in death camps and slaughtered them in the hundreds of thousands 50 years before. Were new massacres in the offing, they wondered? Croats told of persecution in Yugoslavia by Serbian communists, who now plotted to appropriate thousands of square miles in the heart of Croatia for Greater Serbia. The power of nationalist politicians across tottering Yugoslavia grew, and life in Osijek soured. In 1990 Serbs elsewhere in Croatia declared independence, driving Croats from their homes across nearly one-third of the republic. Then in June 1991, Croatia voted to secede from Yugoslavia.

One day the following month, an anguished Croat neighbor appeared at Stula's door; hard men had ordered him to shoot her family if they didn't leave at once. These were not the good people of Osijek, but angry country people—perhaps they'd lost their own homes, Stula says. She boarded an eastbound bus with her three children, her husband followed, and she has not seen her home since.

Stula was part of a first wave; hundreds of thousands more fled at the end of the Croatian war for independence, when Croatian forces overran the breakaway Serb regions with logistical and air support from NATO countries. Hundreds who stayed behind, mostly the elderly, were murdered in the aftermath.

As of 2008, Serbia harbored almost 320,000 people uprooted from the far corners of the former Yugoslavia. About 200,000 came from Kosovo, where Milosevic's response to NATO bombing had been a bizarre scheme to empty large sections of the province of Albanians. When Milosevic folded and more than 850,000 Albanian exiles streamed back from foreign refugee camps, many Serbs fled, knowing they were ripe targets. More were driven out later, despite the presence of international peacekeepers, who sometimes failed to respond as angry mobs attacked unarmed civilians.

The rest came from Croatia, like Stula, or Bosnia. Stula speaks longingly of her lost Croatian home, but she says things could be worse. She found a job as a cook in a restaurant at Delta City, a new luxury mall opened in 2007 by Serbia's richest man. Thanks to the economic reforms of post-Milosevic governments, Serbia's economy has rebounded strongly, with growth in recent years averaging 7 percent. Personal incomes are rising quickly, and the mall is busy every day. It's certainly the best paying job Stula has ever had. But if she can save the money to get European Union travel papers, she plans to leave Serbia for good—maybe go to England, where her oldest son has managed to enroll as a college student.

Stula had patted my arm consolingly when she learned my nationality, as if sorry to be the one to break the news. "America. *Ne dobra. Ne dobra,*" she said. Not good, not good. Why, she asked, does America kick poor people out of their homes in Kosovo? "Bill Clinton, *ne dobra.* Albright, Rice, *ne dobra.* Bush…"

At a small party one night on a houseboat on the Sava River in Belgrade, the upbraiding was less gentle, the sense of grievance far more raw. Two young men with long hair and red faces invited to me to guess how many tons of

Inside a shipping container used as a house, television briefly distracts Radovan Peric and young neighbor Djordje Jovanic from their grim lives as displaced persons. After the 1999 war in Kosovo, some 164,000 Serbs fled. Ethnic violence forced others into camps like this one near Prishtina, Kosovo's capital.


dedicated
war dead
1996, rebel
forces occupied
the city and poured
shells and sniper fi
thousands in an attempt
carve out a Serbian state
multiethnic Bosnia

depleted uranium munitions the U.S. dropped on their country in 1999 and how many cancer cases could result. Did I know about the Serbian civilians killed by U.S. bombing in the Kosovo war? one asked. Not likely, they guessed, as the U.S. media effectively censor material in which Serbs don't appear as latter-day Nazis. They ranged further back, reviewing the tragedies of both World Wars. One of the two—an English speaker who looked like a twentysomething urbanite from anywhere in Europe—seemed on the verge of tears. Did I in fact have any idea of all the things Serbs have suffered?

THERE ■ A VILLAGE in western Serbia called Sljivovica, Serbian for the plum brandy known as slivovitz in English-speaking countries. It's one of a spectrum of fruit-based spirits called *rakija,* central to the social life of Serbs and other Yugoslavs, a drink with which to toast friends and greet visitors. As a village priest in Kosovo said one morning after his wife poured a tiny glass of clear liquid probably well north of 100 proof, good rakija is a fire in the belly, not the throat. With watering eyes, I tried to give the impression all the pain was in my stomach.

But with Serbia edging toward EU membership and in the midst of harmonizing its laws with European standards, can true Serbian rakija survive? Liquor production is tightly regulated in the EU, favoring large distilling companies, while the most prized rakija is homemade, like the priest's.

Sljivovica seemed an apt place to find the kind of domestic rakija makers who might fear joining Europe. Men having coffee at a *kafana* near the highway pointed to a narrow lane running up a nearby hill.

Beside the last house on the road, two men, one young and one old, worked at a blackened pot still that belched smoke and a sweet-sour barnyard odor. Eighty-year-old Ostoja Stanic fed the firebox, while Milan Stanic, 32, poured buckets of fermented plums into a pan. Half an hour later, the mixture began to boil, and a thin stream of alcohol flowed out. Sweet and weak, it is called soft rakija. A second distillation would bring it up to strength. I asked Milan Stanic whether EU bureaucracy could shut down this little still.

He broke into English to emphasize his point: "We want EU."

He showed off some new oak barrels—each holds thousands of liters—near a half-finished concrete building. The Stanic family was about to expand its operation, he said. A larger still was on order. Milan had been consulting agricultural experts about the family's plum crop and researching distillation on the Internet. He indicated an imaginary bottle hovering in front of him, tracing the lines on its label with his finger—"Sljivovica from Sljivovica." As the country grows closer to the rest of Europe, he said, new markets will open, and people who could find only industrialized slivovitz will soon be able to try the real thing. In the cellar of the house, Milan sucked on a plastic tube and siphoned aged rakija into a two-liter bottle. He winked, "I had to learn this during the NATO bombing; it was the only way to get gasoline." The topic is never far from the surface. Then he shook my hand and hurried off to the wedding of an employee of the family's kafana.

Ostoja Stanic stayed behind to mind the still. He spoke of the war of his own youth and the confusing, fratricidal exploits of two rival bands of anti-Nazi resistance fighters: Chetniks, loyal to the Serbian monarchy, and communist fighters led by Tito, Yugoslavia's eventual leader. The Chetniks used to cut people's throats around here, he said. To the teenaged Ostoja, the real heroes were Tito's Partisans, who made a heroic, doomed stand against the Germans in the nearby city of Uzice. But I knew that within a few hours' drive were other old men who could tell how Tito's fighters slaughtered the innocent there. It was a perfect slice of Serbian history—soaked in blood and bravery, with few happy endings or undisputed truths.

But Ostoja Stanic had only been making idle conversation. His real business is making rakija. He handed me the two-liter bottle of slivovitz, patted me on the back when I tried to pay, and went to load firewood into the smoking still. □

A family in southern Serbia rolls past a sign urging, *"Srećan put!*—Have a nice trip!" It could be a farewell wish for their Zastava car. Production ended last fall when Italian carmaker Fiat bought the plant—a step widely seen as a reward from the European Union after Serbia elected a pro-Western government. As the factory is retooled, Serbia's people swing between bitterness over recent hardships and hope for a better future in a nation peacefully integrated into Europe.

COSMIC

The twin-mirrored Large Binocular Telescope in Arizona will deliver images ten times sharper than the Hubble Space Telescope's

VISION

A NEW GENERATION OF GIANT TELESCOPES WILL CARRY THE EYE TO THE EDGE OF THE UNIVERSE.

WINDOW ON THE UNIVERSE Spread across 128 monitors at NASA's Advanced Supercomputing facility in California, colorized red and green nebulae span a vast region of our galaxy. Called hyperwall-2, the system helps researchers visualize huge amounts of data from the latest telescopes.

BY TIMOTHY FERRIS • PHOTOGRAPHS BY JOE MCNALLY

WHEN YOU START STARGAZING WITH A TELESCOPE, two experiences typically ensue. First, you are astonished by the view—Saturn's golden rings, star clusters glittering like jewelry on black velvet, galaxies aglow with gentle starlight older than the human species—and by the realization that we and our world are part of this gigantic system. Second, you soon want a bigger telescope.

Galileo, who first trained a telescope on the night sky 400 years ago this fall, pioneered this two-step program. First, he marveled at what he could see. Galileo's telescope revealed so many previously invisible stars that when he tried to map all of them in just one constellation, Orion, he gave up, confessing that he was "overwhelmed by the vast quantity of stars." He saw mountains on the moon—in contradiction to the prevailing orthodoxy, which declared that all celestial objects were made of an unearthly "ether." He charted four bright satellites as they bustled around Jupiter like planets in a miniature solar system, something that critics of the Copernican sun-centered cosmology had dismissed as physically impossible. Evidently the Earth was a small part of a big universe, not a big part of a small one.

And soon, sure enough, Galileo went to work making bigger and better telescopes. Large light-gathering lenses were not yet available, so he concentrated on making longer telescopes, which produced higher magnifying powers and reduced the halos of spurious colors that afflicted glass lenses in those days. Subsequent observers took the design of glass-lensed, refracting telescopes to great lengths, sometimes literally so. In Danzig, Johannes Hevelius deployed a telescope 150 feet long; hung by ropes from a pole, it undulated in the slightest breeze. In the Netherlands, the Huygens brothers unveiled lanky telescopes that had no tubes at all: The objective lens was perched on a high platform in a field, while an observer up to 200 feet away aligned a magnifying eyepiece and peered through it. Such instruments proffered fleeting glimpses of planets and stars that, like the dance of the seven veils, only aroused a burning desire to see more.

The reflecting telescope, pioneered by Isaac Newton, made it practical to gratify such desires: Mirrors required that only one surface be ground to gather and reflect starlight to a focal point, and since the mirror was supported from behind, it could be quite large without sagging under its own weight, as large lenses tended to do. William Herschel discovered the planet Uranus with a handmade reflecting telescope—he cast his metal mirrors in his garden and basement, and once had to flee from a coursing river of molten metal after the horse-dung mold fractured. Spiral-armed galaxies were first glimpsed through a massive reflecting telescope, with a six-foot diameter primary mirror, that Lord Rosse constructed on his estate in Ireland.

Today's largest telescopes have mirrors up to some ten meters (33 feet) in diameter, with quadruple the light-gathering power of the legendary five-meter Hale Telescope at Palomar Observatory in southern California. Looming large as office buildings, some of these giants are so highly automated that they can dust off their optics at sundown, open the dome, sequence and carry out observations throughout the night, and shut down come threatening weather, all with little or no human intervention. Yet humans, being human, still intervene a lot, if only to make sure nothing goes awry: To lose just one night's work at a big telescope these days is to squander as much as $100,000 in operating costs.

SCALA/ART RESOURCE

BEGINNINGS Four hundred years ago Galileo gave birth to modern astronomy with the humblest of instruments, now preserved at a history of science museum in Florence, Italy. A one-and-a-half-inch lens displayed in an ornate frame (left, at bottom) was ground in 1609. Others followed. Fitted into simple wooden tubes just a few feet long, Galileo's lenses magnified the heavens, bringing Earth's moon, sunspots, and nearby planets into focus.

Three of today's largest telescopes—Gemini North, Subaru, and Keck—stand within hailing distance of one another atop the nearly 14,000-foot peak of Hawaii's Mauna Kea, an inactive volcano. The altitude puts them above 40 percent of Earth's atmosphere—and most of its water vapor, which is opaque to the infrared wavelengths the astronomers like to study—but also makes it difficult for the astronomers and engineers who work there to breathe and think. Many wear clear-plastic oxygen tubes in their nostrils as routinely as we might wear eyeglasses. Others rely on the body's ability to adapt but worry about making what they call a CLM, or "career-limiting mistake." "At altitude, we don't improvise; that would be a disaster," says Gemini astronomer Scott Fisher. "We're kind of trained monkeys up here. The real thinking goes on at sea level."

These big Mauna Kea observatories are comparably smart and costly, yet each exudes a distinct personality. The 8.1-meter Gemini telescope is housed in an onion-shaped silver dome ringed by a set of shutters that, when closed during the day, make the observatory look as ungainly as a fat man in an inner tube. But the shutters open at dusk to create an enormous set of windows, three stories tall and stretching nearly three-quarters of the way around the observatory, that let in the night air and happen to afford a panorama of the blue Pacific all the way to Maui and beyond. Gemini's four main digital detectors—cameras and spectrometers, heavy as cars and costing around five million dollars each—are attached to a carousel surrounding the telescope's focal point, where they can be rotated into place in minutes. Computers run the telescope by night, shuffling requested observations to make the most of every minute. "We're all about nighttime efficiency," says Fisher.

The Subaru telescope's instruments are housed in alcoves like jeroboams of champagne in a heavenly wine cellar. (The comparison is not entirely fanciful; one leading Japanese

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Timothy Ferris has written eight books, and made three films, on astronomy. Joe McNally has specialized in science and technology for the Geographic.

astronomer propitiates the gods at the start of each Subaru observing run by pouring vintage sake on the ground outside the dome at the four points of the compass.) When a particular instrument is required, a robotic yellow trolley makes its way to the alcove, picks up the detector, ferries it to the bottom of the massive telescope, and locks it in place, attaching the data cables and the plumbing for the detector's refrigeration system. Subaru happens to be one of the few giant telescopes that anybody has ever actually looked through. For its inauguration in 1999, an eyepiece was attached so that Princess Sayako of Japan could have a look through the scope, and for several nights thereafter eager Subaru staffers did the same. "Everything you can see in the Hubble Space Telescope photos—the colors, the knots in the clouds—I could see with my own eyes, in stunning Technicolor," one recalled.

A TELESCOPE DOESN'T JUST SHOW YOU WHAT'S OUT THERE; IT IMPRESSES UPON YOU HOW LITTLE YOU KNOW.

Keck consists of two identical telescopes. Both have ten-meter mirrors made of 36 segments; with its support structure, each segment weighs close to a thousand pounds, costs close to a million dollars, and would suffice to create a fine, university-grade telescope on its own. The telescopes' "tubes" are spindly steel skeletons that look as delicate as spiders' webs but are more precisely configured than a racing sloop's rigging. "We use the telescope's mission to motivate ourselves," one Keck astronomer told me. "If a little wire or something is found intruding into the optical path, we think, If the light has been traveling through space for 90 percent of the history of the universe, and it got this close to the telescope, we'd better make sure it gets the rest of the way."

Few of the astronomers awarded time on the big telescopes actually go there to observe anymore. Most submit their requests electronically—on a recent night at Gemini, the scheduled projects ranged from "Primordial Solar System Masses" to "Magnetic Activity in Ultracool Dwarfs"—and the results are sent back to them. Geoff Marcy, a modern-day Prince Henry the Navigator whose team has discovered more than 150 planets orbiting stars other than our sun, gets more observing time than most at Keck but has not been there for years. Instead, his extrasolar planet team observes from a remote operating facility at UC Berkeley. During observing runs, Marcy reports, "we settle into a routine of working all night. We have all our books and other resources here at hand, plus enough normal life so our spouses don't forget us."

IN ADDITION TO their unprecedented light-gathering power, today's big telescopes benefit from their adaptive optics (AO) systems, which compensate for atmospheric turbulence. The turbulence is what makes stars glitter; telescopes magnify every twinkle. A typical AO system fires a laser beam into a thin layer of sodium atoms 56 miles high in the atmosphere, causing them to glow. By monitoring this artificial star, the system determines how the air is churning and adjusts the telescope's optics more than a thousand times each second to compensate. Gemini pays a pair of students ten dollars an hour to sit outside the dome all night, walkie-talkies in hand, ready to warn the astronomers to turn off the laser should an airplane approach. "It's incredible to see in practice," says Scott Fisher. "When the AO system is off, you see a nice, pretty star that looks a little fuzzy. Turn the AO on, and the star just goes *phonk!* and collapses to a tiny point."

Objects in the night sky are measured in

MIRROR WORKS Ten-pound glass chunks (above) are loaded into a honeycombed mold at the University of Arizona. Hollow chambers reduce mass and help produce a lightweight mirror that adjusts more quickly to ambient temperature changes. As the glass melts, the mold (below) spins to create a concave surface that gathers distant light and refocuses it inside a telescope.

BOTH ■ MARK THIESSEN, NG PHOTOGRAPHER

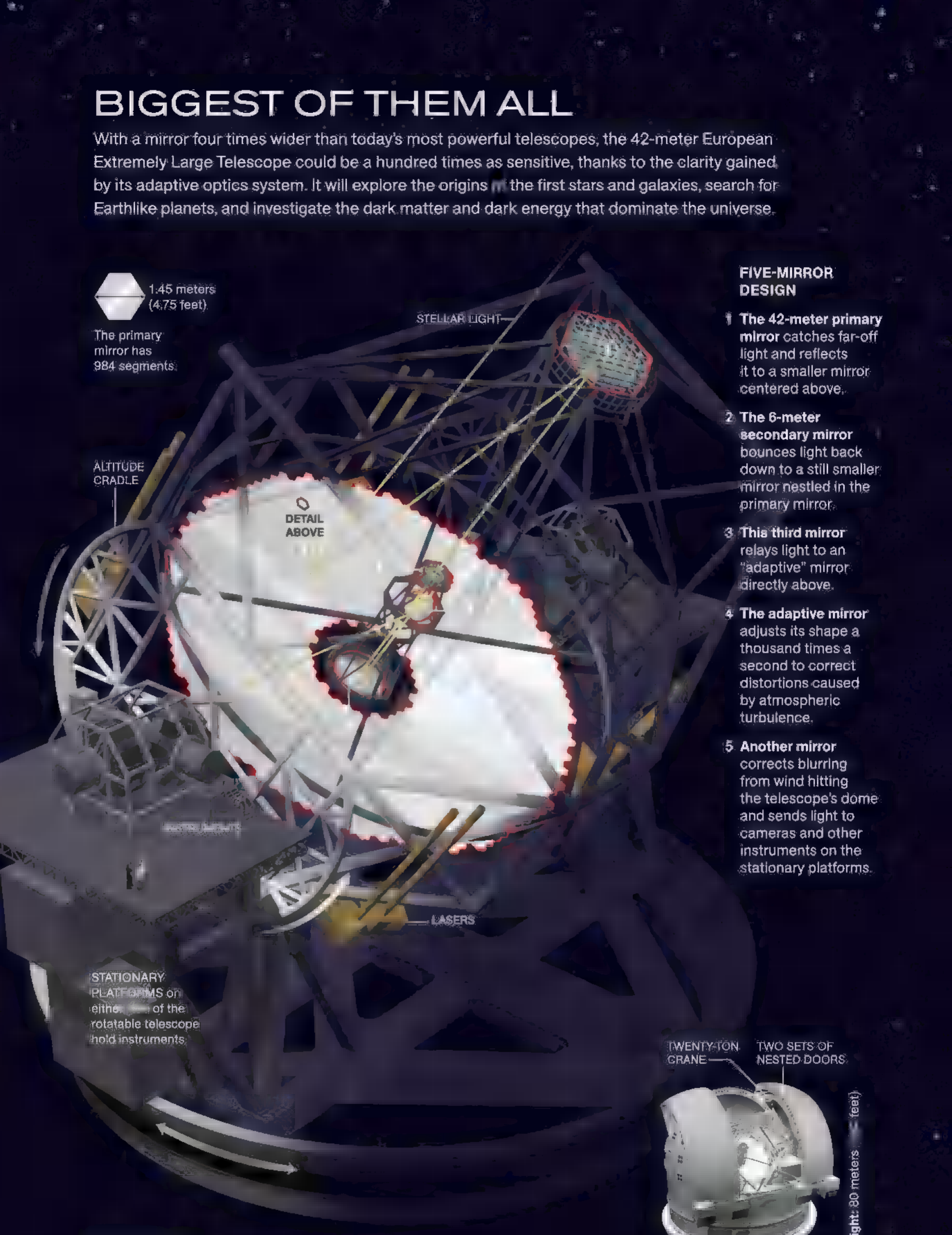
DETAIL MAN Beneath the University of Arizona football stadium, a technician pores over the surface of the 8.4-meter Large Synoptic Survey Telescope mirror, looking for major flaws. Over ■ period of months the glass will be polished to within one millionth of an inch of the precise concave shape required. A thin coating of aluminum will create the reflective surface.

BIGGEST OF THEM ALL

With a mirror four times wider than today's most powerful telescopes, the 42-meter European Extremely Large Telescope could be a hundred times as sensitive, thanks to the clarity gained by its adaptive optics system. It will explore the origins of the first stars and galaxies, search for Earthlike planets, and investigate the dark matter and dark energy that dominate the universe.

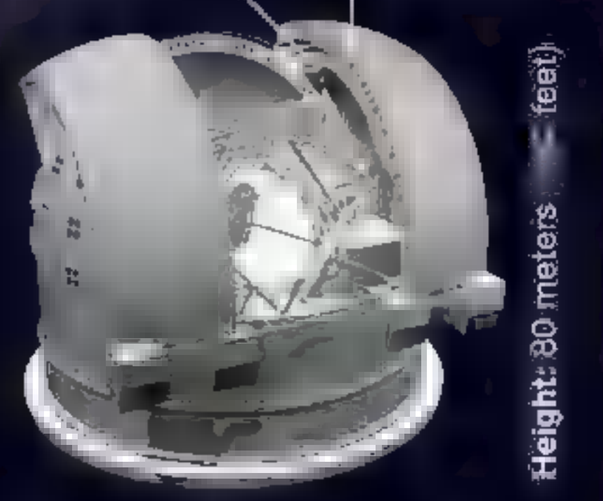
1.45 meters (4.75 feet)

The primary mirror has 984 segments.



FIVE-MIRROR DESIGN

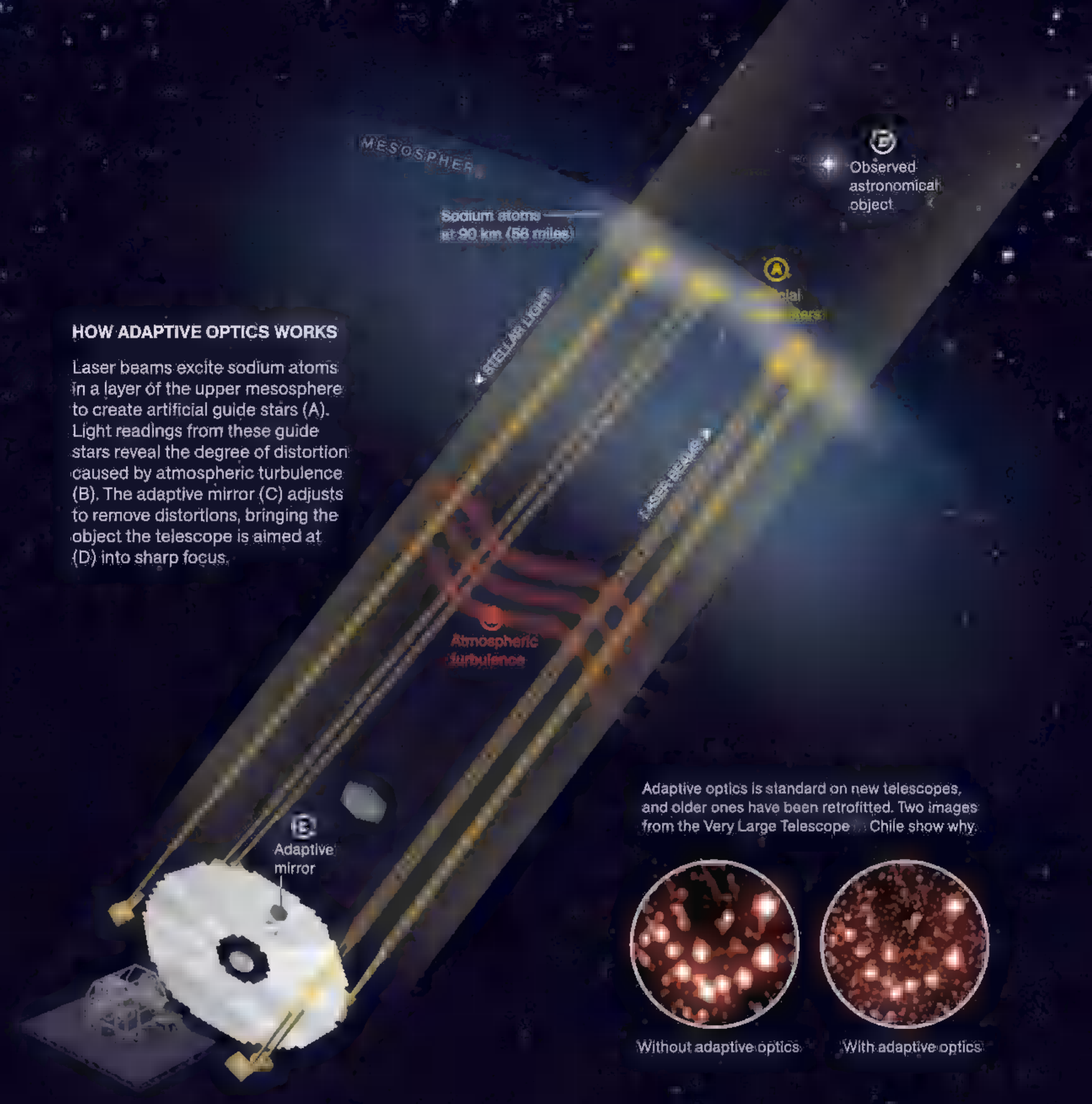
1. **The 42-meter primary mirror** catches far-off light and reflects it to a smaller mirror centered above.
2. **The 6-meter secondary mirror** bounces light back down to a still smaller mirror nestled in the primary mirror.
3. **This third mirror** relays light to an "adaptive" mirror directly above.
4. **The adaptive mirror** adjusts its shape a thousand times a second to correct distortions caused by atmospheric turbulence.
5. **Another mirror** corrects blurring from wind hitting the telescope's dome and sends light to cameras and other instruments on the stationary platforms.



Diameter: 100 meters (328 feet)

HOW ADAPTIVE OPTICS WORKS

Laser beams excite sodium atoms in a layer of the upper mesosphere to create artificial guide stars (A). Light readings from these guide stars reveal the degree of distortion caused by atmospheric turbulence (B). The adaptive mirror (C) adjusts to remove distortions, bringing the object the telescope is aimed at (D) into sharp focus.



Adaptive optics is standard on new telescopes, and older ones have been retrofitted. Two images from the Very Large Telescope in Chile show why.

Without adaptive optics | With adaptive optics

UPCOMING TELESCOPES

8-10 m (26-33 ft) — Size of today's largest mirrors

Name	Large Synoptic Survey	Giant Magellan	Thirty Meter	European Extremely Large
Location	Cerro Pachón, Chile	Las Campanas, Chile	Chile or Hawaii	Argentina, Chile, or Canary Islands
Primary mirror diameter	8.4 m	Seven 8.4-m mirrors	30 m	42 m
Estimated completion	2016	2018	2018	2018

Dome covers not shown

HIRAM HENRIQUEZ, NG STAFF; LINDSAY SERRA, ART BY DON FOLEY
SOURCE: EUROPEAN SOUTHERN OBSERVATORY (E-ELT DATA AND VLT IMAGES)

degrees, the full moon spanning about one half of a degree. Without AO, a powerful telescope on a fine night can perceive objects separated from each other by as little as one 3,600th of a degree, or one arc second. Thanks to Keck's AO system, UCLA astronomer Andrea Ghez was able to make a motion picture of seven bright stars whirling around the invisible black hole at the center of our galaxy over a period of 14 years: The entire movie takes place *inside* a box measuring only one arc second on a side. Based on the frenzy of the stars in the grip of the black hole, Ghez calculated that it has a mass of four million suns, generating enough gravitational force to slingshot some stars that pass too close right out of our galaxy. Several such hypervelocity stars have been located, speeding off toward the depths of intergalactic space like party crashers ejected from an exclusive nightclub.

ONE DAY, OBSERVATORIES SITTING IN CRATERS ON THE FAR SIDE OF THE MOON MAY PROBE THE UNIVERSE FROM IDEAL SURROUNDINGS.

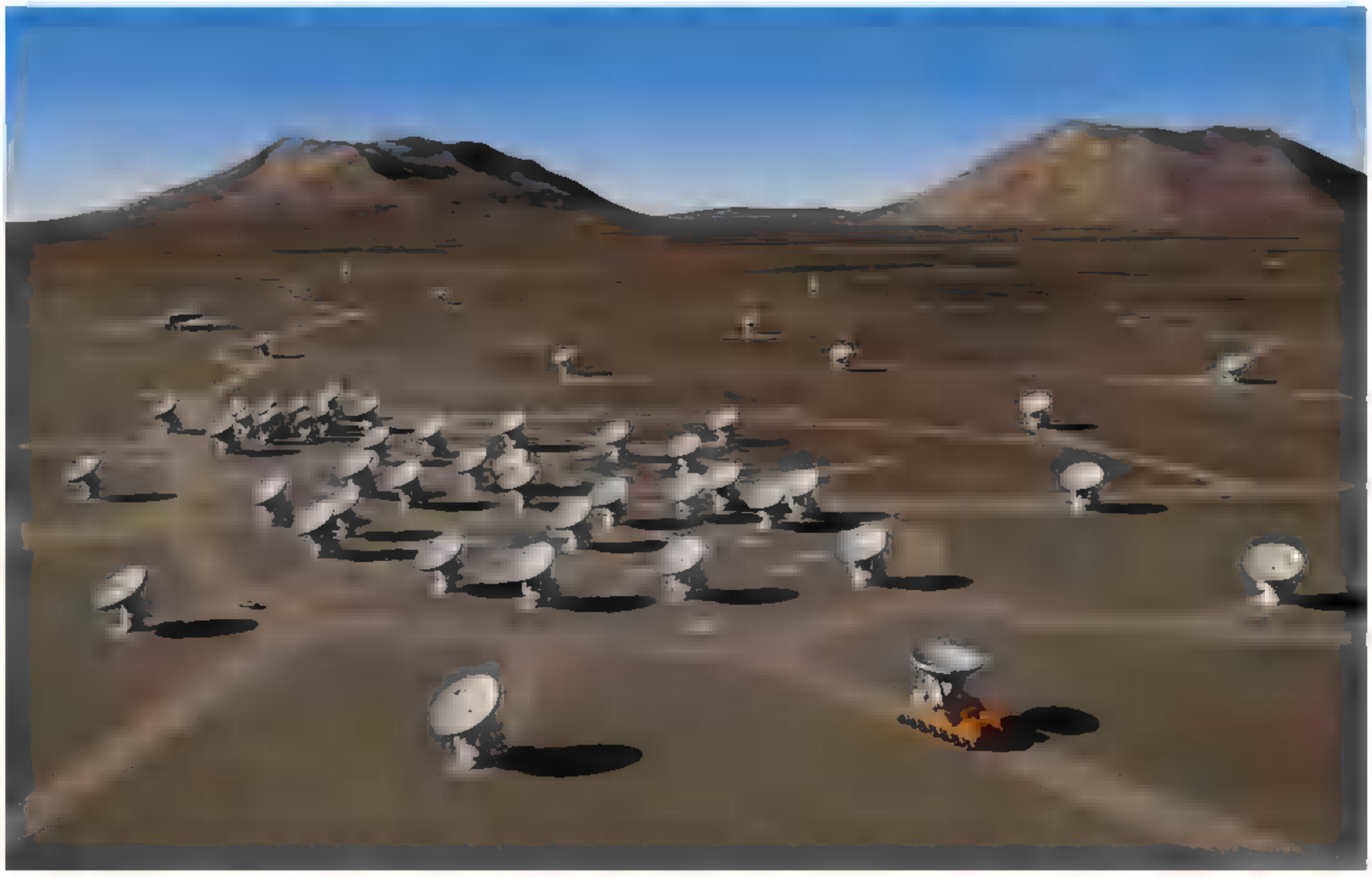
What's next? Even bigger telescopes, of course, with the capability to shoot cosmic pictures faster, wider, and in even greater detail. Among the behemoths due to come on line within a decade are the Giant Magellan Telescope, the Thirty Meter Telescope, and the 42-meter European Extremely Large Telescope—a scaled-down version of the 100-meter Overwhelmingly Large Telescope, which was tabled at the planning stage when its projected budget turned out to be overwhelming too.

Particularly innovative is the Large Synoptic Survey Telescope, or LSST, whose 8.4-meter primary mirror was cast last August in a spinning furnace under the stands of the University of Arizona Wildcats' football stadium in Tucson. (The rotation technique produces a mirror blank that is already concave, reducing the amount of glass that must be ground away to bring the mirror to a proper figure.) Conventional telescopes have narrow fields of view, typically spanning no more than half a degree on a side—much too narrow to take in the enormous patterns that grew out of the big bang. The LSST will have a field of view covering ten square degrees, the area of 50 full moons. From its site in the Chilean Andes, it will be able to image galaxies far across the universe in exposures of just 15 seconds each, capturing fleeting events to distances of over ten billion light-years, 70 percent of the way across the observable universe. "Since we'll have a big field of view, we can take a whole lot of short exposures and—*bang, bang, bang, bang*—cover the entire visible sky every several nights, and then repeat," says LSST Director Tony Tyson. "If you keep doing that for ten years, you have a movie—the first movie of the universe."

The LSST's fast, wide-angle imaging could help answer two of the biggest questions confronting astronomers today: the nature of dark matter and of dark energy. Dark matter makes its presence known by its gravitational attraction—it explains the rotation speed of galaxies—but it emits no light, and its constitution is unknown. Dark energy is the name given to the mysterious phenomenon that, for the past five billion years, has been accelerating the rate at which the universe expands. "It's a little bit scary," says Tyson, "as if you were flying an airplane and suddenly something unknown took over the controls."

The LSST could help solve these immense riddles thanks in part, oddly enough, to the science of acoustics. The big bang was *noisy*. Although sound cannot propagate through the vacuum of today's space—as pedants are fond of reminding the directors of science-fiction

WIDE RECEIVERS Massive trucks will drive 66 12- and 7-meter antennas into the Chilean desert to form ■ single huge radio telescope spanning miles (rendering below). The Atacama array will collect data from within the clouds of dust and gas that gave rise to stars, planets, and galaxies. "It will enable us finally to penetrate cold, dark regions of the universe," says project scientist Richard Hills.



FROM TOP: PASCAL MARTINEZ, ESO; HERBERT ZODET, ESO

SHARPER SIGHT The 5.1-meter Hale Telescope on Palomar Mountain, California, has done cutting-edge science for 60 years, making key discoveries about galaxies and quasars. An adaptive optics laser that shoots 56 miles up now lets Hale produce even sharper and more detailed views.

films—the early universe was a thick plasma and as alive with sound as a drummers convention. Certain tones resonated in the primordial plasma, like the tones of struck wine glasses, and these harmonies, etched into sheets of galaxies that today shamble across billions of light-years, contain precise information about the nature of dark matter and dark energy. If astronomers can map these large-scale structures accurately, they should be able to identify the signatures of dark matter and dark energy in the big bang's harmonics. The Sloan Digital Sky Survey, a pioneering wide-angle study, captured some of this information when it mapped the sky from 1999 through 2008. The LSST is designed to go much deeper into cosmic space. It may not resolve the mysteries, but, predicts Tyson, "it will go a long way toward showing what dark energy and dark matter aren't."

WHAT'S NEXT? EVEN BIGGER TELESCOPES, WITH THE CAPABILITY TO SHOOT COSMIC PICTURES FASTER, IN EVEN GREATER DETAIL.

The LSST's photographic "speed" will also give astronomers a better look at events too short-lived to be readily studied today. Most astronomers, even amateurs using backyard telescopes and off-the-shelf digital cameras, regularly record fleeting events of unknown origin. You take a series of digital exposures, and in one of them a spot of light appears where none was before or after. It may have been a cosmic ray hitting the light-detection chip, a high-velocity asteroid hurtling through the field of view, or a blue flare on the surface of a dim red star. You just don't know, so you shrug and move on. Because the LSST will take so many repeat exposures of the entire sky, it could resolve many such riddles.

Tomorrow's enormous telescopes will do as much in one night as today's do in a year, but that will not necessarily render the older telescopes obsolete. When the giants come on line, says Scott Fisher, "the Geminis of today will become the telescopes that get to go out and do the surveys," finding interesting phenomena for the largest scopes to investigate in detail. "It's like a pyramid, and it feeds both ways: When a really big telescope finds something exciting that we can't spend every night observing, the astronomers can apply for time on a smaller telescope to, say, check it out every clear night for a year and see how it changes over time."

Orbiting space telescopes are opening up another dimension. NASA's Kepler satellite, which launched in March 2009, is methodically imaging the constellation Cygnus, looking for the slight dimming of light caused when planets—some perhaps Earthlike—transit in front of their stars; Geoff Marcy's team will then use Keck to scrutinize stars flagged by Kepler to confirm that they have planets. In the future, pairs of mirrors deployed in orbit and linked by laser-ranging systems could attain the resolving power of telescopes measuring thousands of meters across. One day, observatories sitting in craters on the far side of the moon may probe the universe from surroundings ideally quiet, dark, and cold. The coming combination of smart satellites talking to big, increasingly automated ground telescopes, themselves linked together by fiber-optic networks and employing artificial intelligence systems to search out patterns in the torrents of data, suggests a process as much biological as mechanical, akin to the evolution of global eyes, optic nerves, and brains.

FILM DIRECTORS LIKE TO SAY that each movie is really two movies—the one you make, and the one you say you're going to make while raising the money. The point is that nobody can accurately predict the outcome of any genuinely

CLOUD FREE Crowded in prime territory, the Subaru, Keck I and II, and NASA infrared telescopes (left to right) sit atop Hawaii's 13,796-foot Mauna Kea. Set above 40 percent of the atmosphere, they offer one of Earth's clearest views into space.

creative venture. The same is true of scientific discovery: Scientists can explain what they expect to accomplish with bigger and better telescopes, but such predictions are mostly just extrapolations from the past. "If you're going to Washington to seek funding for a new telescope and you make a list of what you'll see through this new window on the universe, you know that the most interesting thing it will discover is probably not on your list," says Tyson. "It's likely to be something totally new, some out-of-the-box physics that's going to blow our minds."

The marvelous model of the big-bang universe pieced together in the 20th century arose largely from just such unanticipated discoveries. Edwin Hubble discovered the expansion of the universe accidentally, at the telescope: Cosmic expansion had been implied by Einstein's general theory of relativity, but Hubble knew nothing of the prediction, and not even Einstein had taken it seriously. Dark matter was discovered accidentally; so was dark energy. A telescope doesn't just show you what's out there; it impresses upon you how little you know, opening your imagination to wonders as big as all outdoors. "The spyglass is very truthful," said Galileo. □

TRIPLE VISION Portraits of the Crab Nebula captured in visible, infrared, and x-ray wavelengths (left to right) are projected on screens in Monument Valley, Utah, in a long exposure beneath a star-filled sky. Telescopes of the next decade will reveal our universe in ways never known before.

Clad in his signature red tie, socks, and sneakers, Garrison Keillor reports from a racetrack near Iowa's State Fair grandstand.

ON ASSIGNMENT **Carnival Connoisseur** Garrison Keillor's mellifluous voice is practically as American as apple pie. Since 1974 he's been telling stories from the fictional Minnesota town of Lake Wobegon every Saturday on his radio show, *A Prairie Home Companion.* This month Keillor chronicles the goings-on at a place that does exist, if only for a short time: the great American state fair. He hit several of these "ritual carnivals" last summer, but he remembers the day this photo was taken at the Iowa fair particularly well. It was shortly after his 66th birthday, and he'd just made a friend in the dressing room. "Senator Tom Harkin and his wife came and visited me there, and he ironed my shirt," he says. Keillor was busy shaving when the Iowa senator explained to him that as a child he had learned to "iron a good shirt." Keillor hosted a live performance of his radio show that evening and recalls the ideal setting: "An Iowa crowd on a warm summer night, who've eaten some ice cream and a pork chop on a stick—no better audience in the world. There isn't much you can do to put a dent in their day."

PHOTO: JOEL SARTORE

INSIDE GEOGRAPHIC

Robert Clark stands at the Victory Gate in Cambodia.

ON ASSIGNMENT **Angkor Man** Ants feasted relentlessly upon Robert Clark as he photographed the ruins of the Khmer Empire city for this month's "Divining Angkor" feature. The bugs were distracting the day this picture was taken at the temple complex of Angkor Thom, but news from home diverted his attention. "It was the day Obama got elected," he says. When his wife called from Manhattan to give him the word, Clark pondered his locale. "I was at the Victory Gate. I thought that was fitting." For more on the empire, catch the National Geographic Channel's *Secrets of Angkor*, airing July 14 at 9 p.m.

NATIONAL GEOGRAPHIC CHANNEL

Geopuzzle Answers

A	T	M	■	■	A	S	H	O	R	E	■	R	A	M
F	R	O	G	■	S	H	O	V	E	L	■	A	D	A
R	U	N	L	I	K	E	K	E	C	K	■	K	O	S
A	S	T	O	R	S	■	I	N	T	E	G	E	R	S
I	T	E	M	S	■	M	E	S	■	■	A	S	I	A
D	E	G	■	■	C	O	S	■	L	O	W	I	N	G
■	D	O	M	E	O	N	T	H	E	R	A	N	G	E
■	■	■	A	S	E	A	■	O	N	E	I	■	■	■
A	L	T	I	T	U	D	E	C	Y	G	N	U	S	■
P	E	E	L	E	R	■	A	K	A	■	■	■	A	M
P	A	L	E	■	■	D	T	S	■	T	O	R	M	E
A	V	E	■	A	G	E	S	■	G	A	L	O	O	T
R	E	X	■	H	A	L	O	G	O	O	D	B	Y	E
E	N	E	■	A	T	T	U	N	E	■	S	E	E	R
L	S	D	■	S	T	A	T	U	S	■	■	D	D	S

SPECIAL ISSUE **Your Shot** Readers have submitted more than 100,000 photographs to *National Geographic*'s Your Shot since that section's debut in March 2006. We usually have space to run just two of these images. This month we're publishing more than a hundred in our new collector's edition. The special—with this cover (right)—is available June 30 for $10.99 at newsstands, in bookstores, and on *ngm.com*. You can also order it online with a custom cover using your own downloaded photograph: *Your Shot* with your own shot.

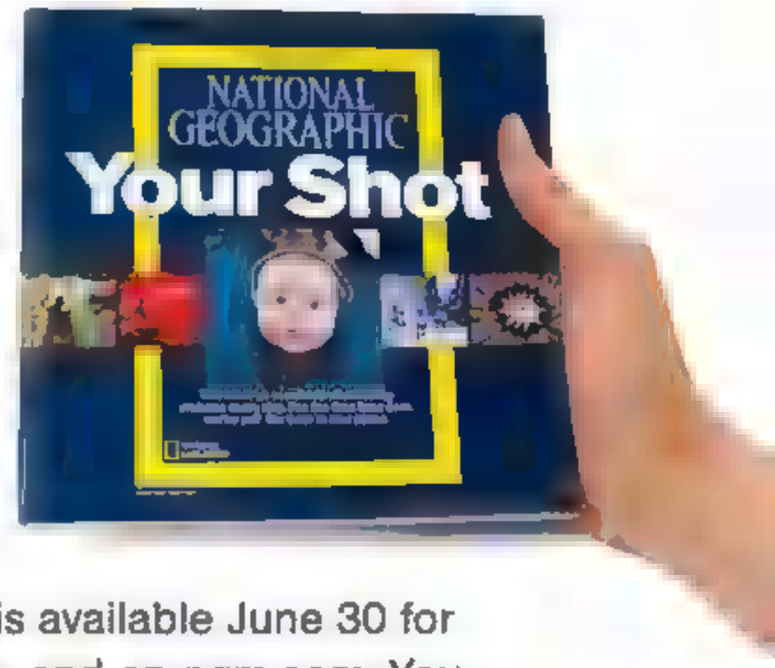


PHOTO: DAVID COVENTRY

FLASHBACK

Searching for Home In 1918, New York photographer Lewis Hine—already known for his haunting portraits of Ellis Island immigrants and child laborers—arrived in Paris. He'd been hired by the American Red Cross to document its European relief efforts. In the waning months of World War I and after the armistice, Hine traveled through France, Belgium, and the Balkans shooting the shattered continent. He photographed this young Serbian refugee in the town of Grdjelitza. Text accompanying additional Grdjelitza photos by Hine notes: "With not even a roof over their heads, these families were finding their way back home on foot from northern Serbia where the Austrians and Germans had sent them to produce food for the enemy… When these people reach home, it will not be home, but simply ruins." *—Margaret G. Zackowitz*

Flashback Archive Find all the photos at **ngm.com.**

PHOTO: LEWIS W. HINE, NATIONAL GEOGRAPHIC STOCK

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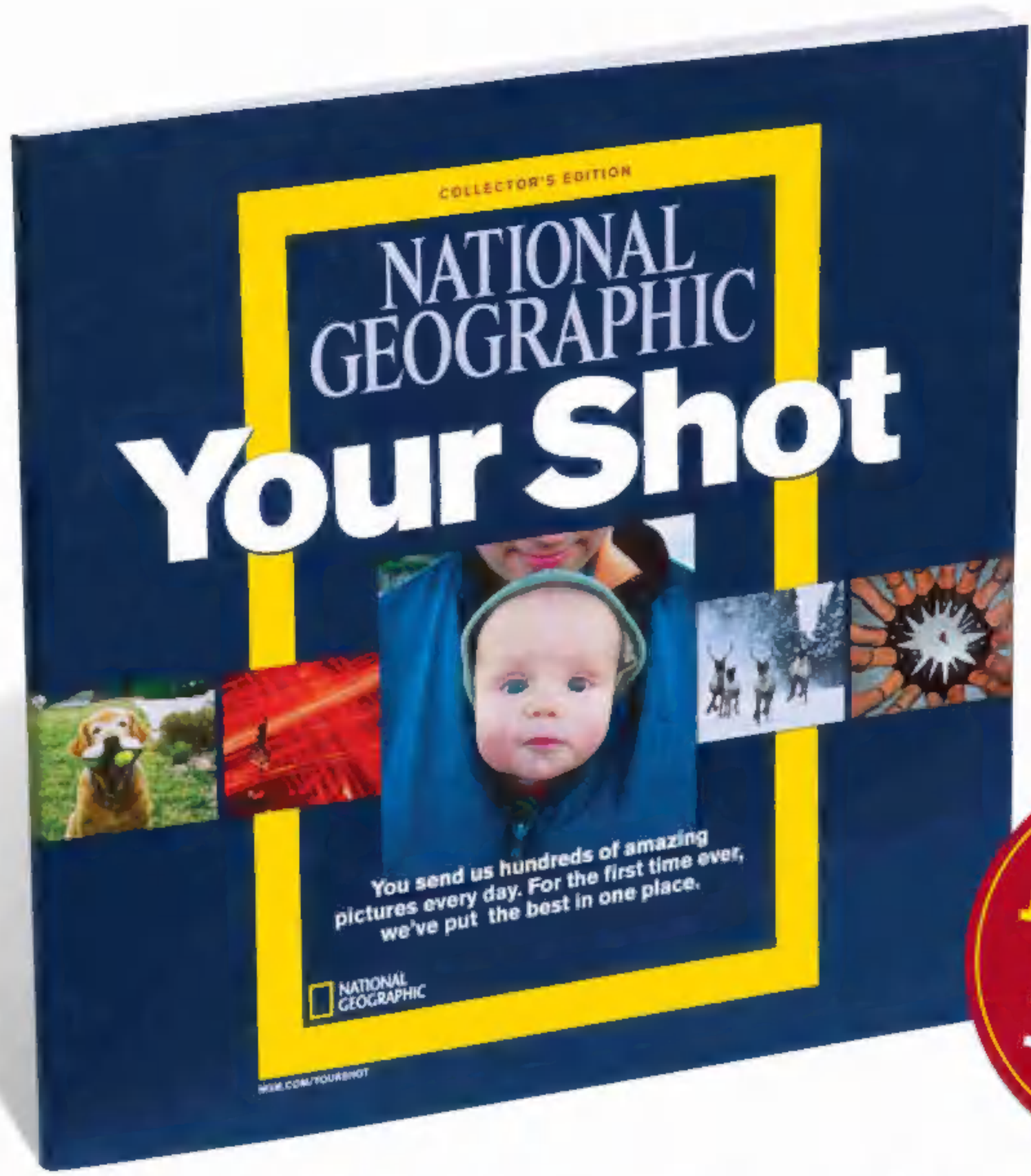
NATIONAL GEOGRAPHIC



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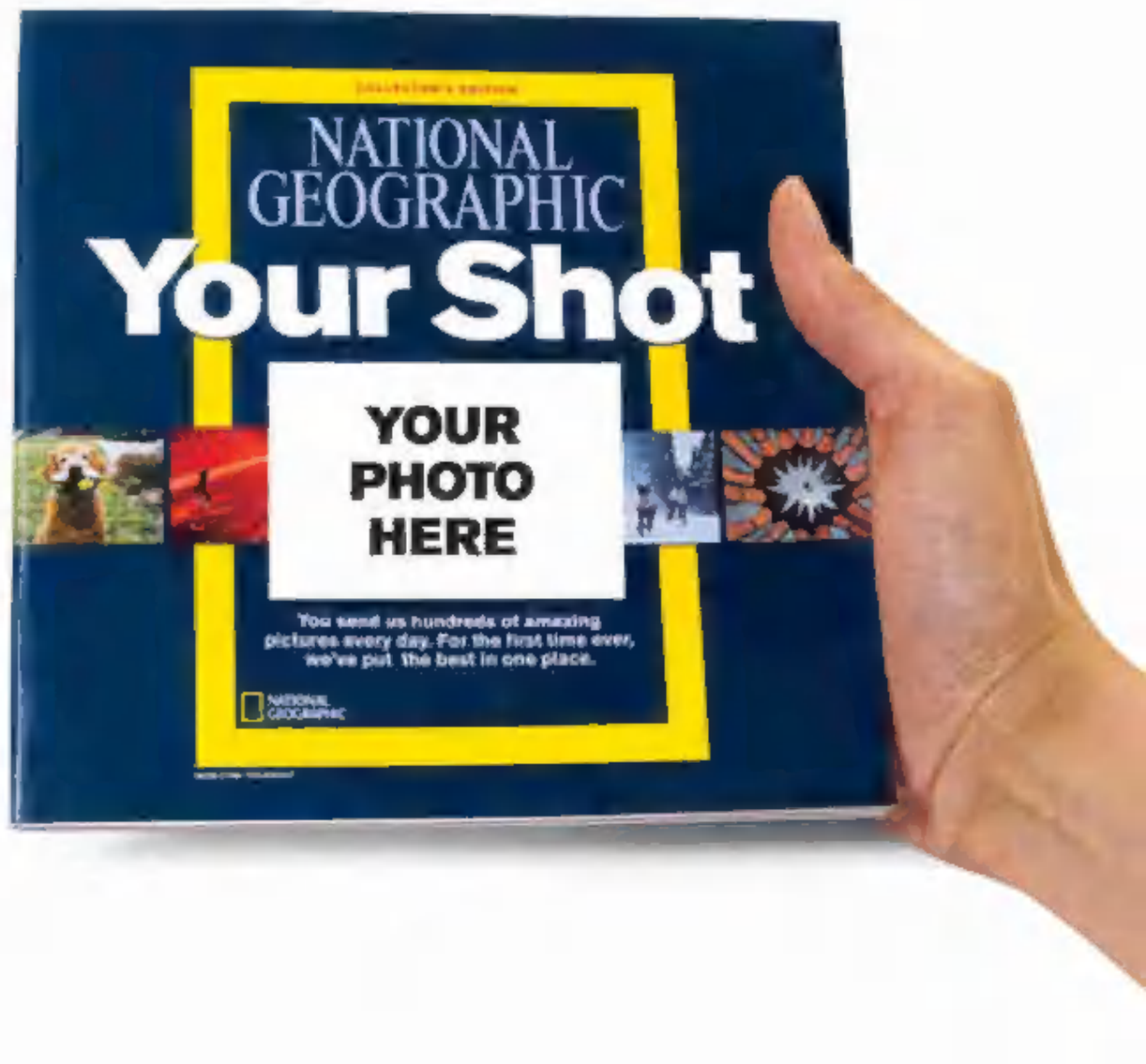

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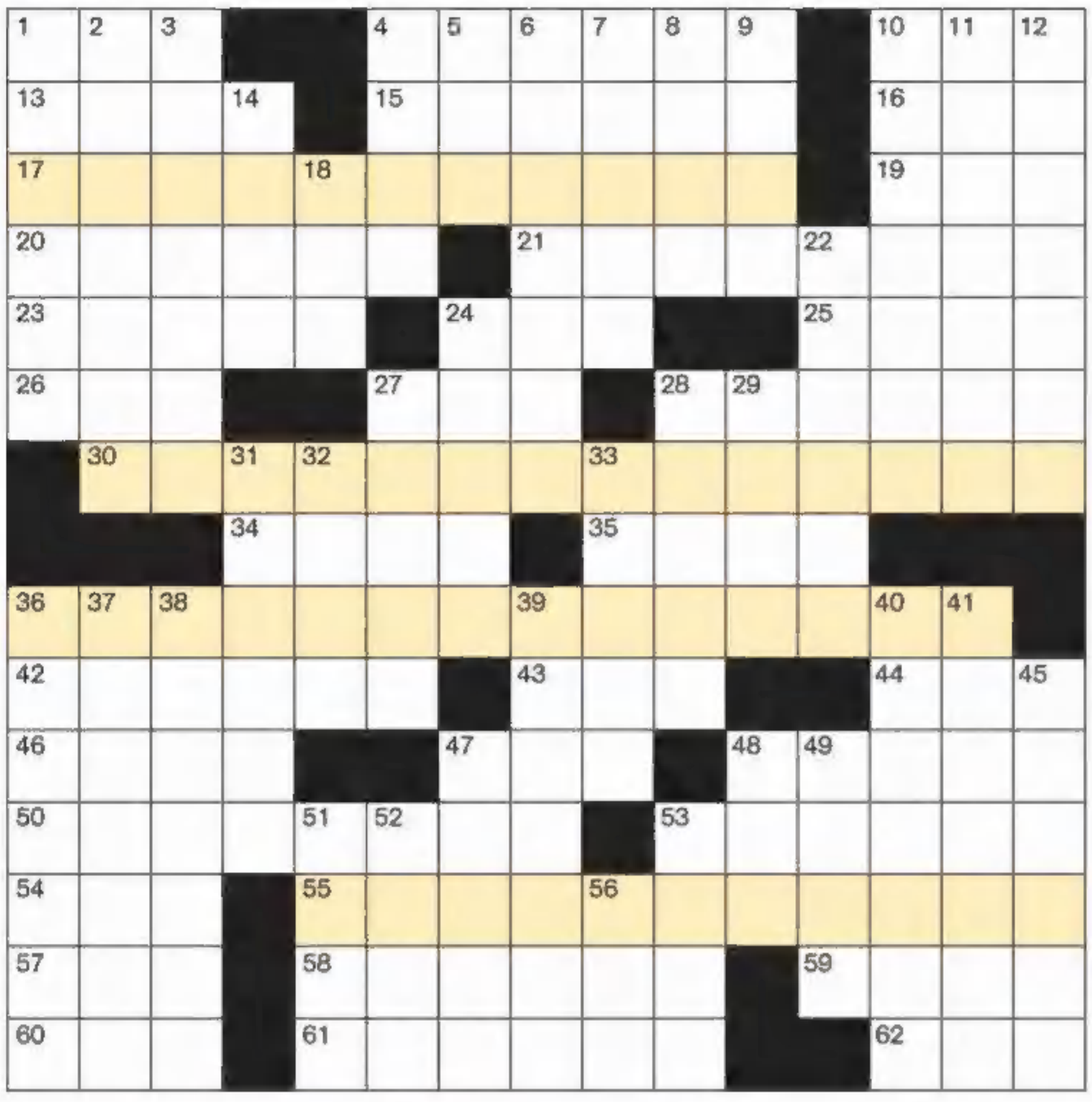

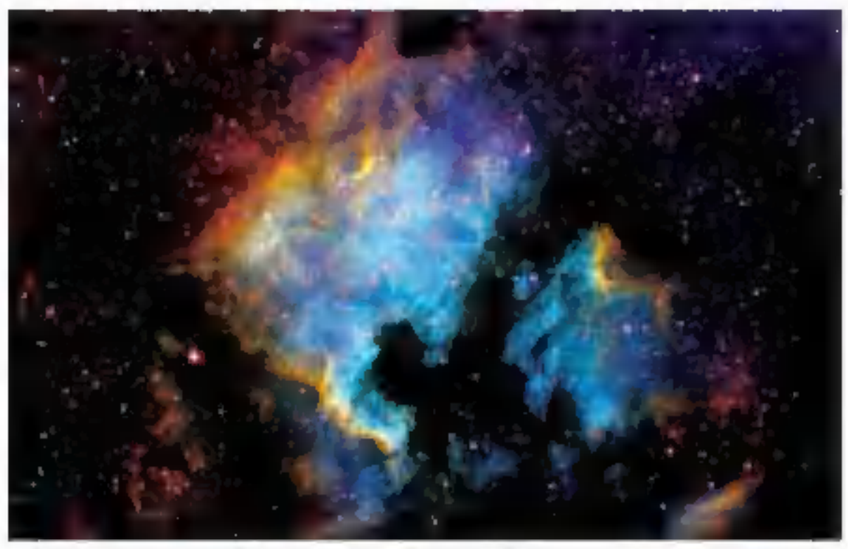

Cosmic Hook

Puzzle by Cathy Allis

Word puzzles are as old as Pompeii and as new as the GeoPuzzle, which debuts this month. Tinted clues offer a punning tie to the telescope story on page 120. The nebula at left sits in the constellation named in the answer to 36 across.

ACROSS

1 Where bread is spit out?
4 How driftwood may be washed
10 Lamb pop
13 Kind of swimming kick
15 Gardener's need
16 Oklahoma city, site of the Chickasaw Nation headquarters
17 Function in the manner of a Mauna Kea telescope?
19 Boxing stats
20 Famed furrier's family
21 Whole numbers
23 Articles
24 My in Montreal or month in Madrid
25 China setting
26 Astronomers' meas. equal to 3,600 arc seconds: abbr.
27 Button on a sci. calculator
28 Doing mooing
30 Housing for a telescope in, say, the Andes?
34 On the briny
35 "Dedicated to the __ Love"
36 Constellation the Kepler satellite will image from on high?
42 Kitchen gadget
43 Letters preceding an alias
44 "Hanoi Hilton" setting
46 Wan
47 Wino's withdrawal woe
48 Crooner Mel, "The Velvet Fog"
50 Means, e.g.
53 Lummox
54 Cornish or Devon __ (cat breed)
55 Astronomers' tribute to improved optics?
57 Compass dir.
58 Bring into harmony
59 Fortune-teller
60 Drug Dr. Leary dropped
61 Social climber's goal
62 Letters on some ADA members' shingles

DOWN

1 In a panic
2 Reliable
3 __ Bay, Jamaican city
4 Says "Who?"
5 Yonder ewe or yacht
6 Maximally corny
7 Tandoor, kiln, etc.
8 Prefix with angular
9 Screen star Sommer
10 Earns, big-time
11 Worshipful
12 Spa specialty
14 Latch (onto)
18 E-filing destination
22 Knighted nephew of King Arthur
24 Single-celled microorganism
27 __ d'Alene, Idaho Panhandle city
28 Singer Lotte, Kurt Weill's wife
29 Neighbor of Wash.
31 Special-purpose envelope
32 Direction from which *el sol* rises
33 Joints in horse hind legs
36 Raiment
37 Adds yeast to
38 Messaged, an outdated way
39 Opts for a restaurant experience
40 Not in one's choir garment, e.g.
41 White reindeer-herding dog
45 The diameter of telescope Subaru's primary mirror is 8.2 of these
47 Nile's mouth formation
48 Chinese "way"
49 Nickname for a bygone classic American car
51 Sounds from successful solvers
52 Commerce treaty before NAFTA
53 Leaves
56 Serengeti antelope

Answers in Inside Geographic

IMAGE: DON TAYLOR

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